

FOCUS

WHEN BLACK HOLES COLLIDE

WHAT THEY TELL US ABOUT THE MYSTERIES OF THE UNIVERSE

WONDERS OF THE DRONE AGE

The flying robots uncovering hidden corners of the world

Q&A

Can your dog catch a cold?

What makes stars explode?

How much rubbish is on the Moon?

THE ALLERGY FALLACY

The real garden that will grow on Mars

Are chimps spiritual?

New forensic breakthroughs catching up to the criminals



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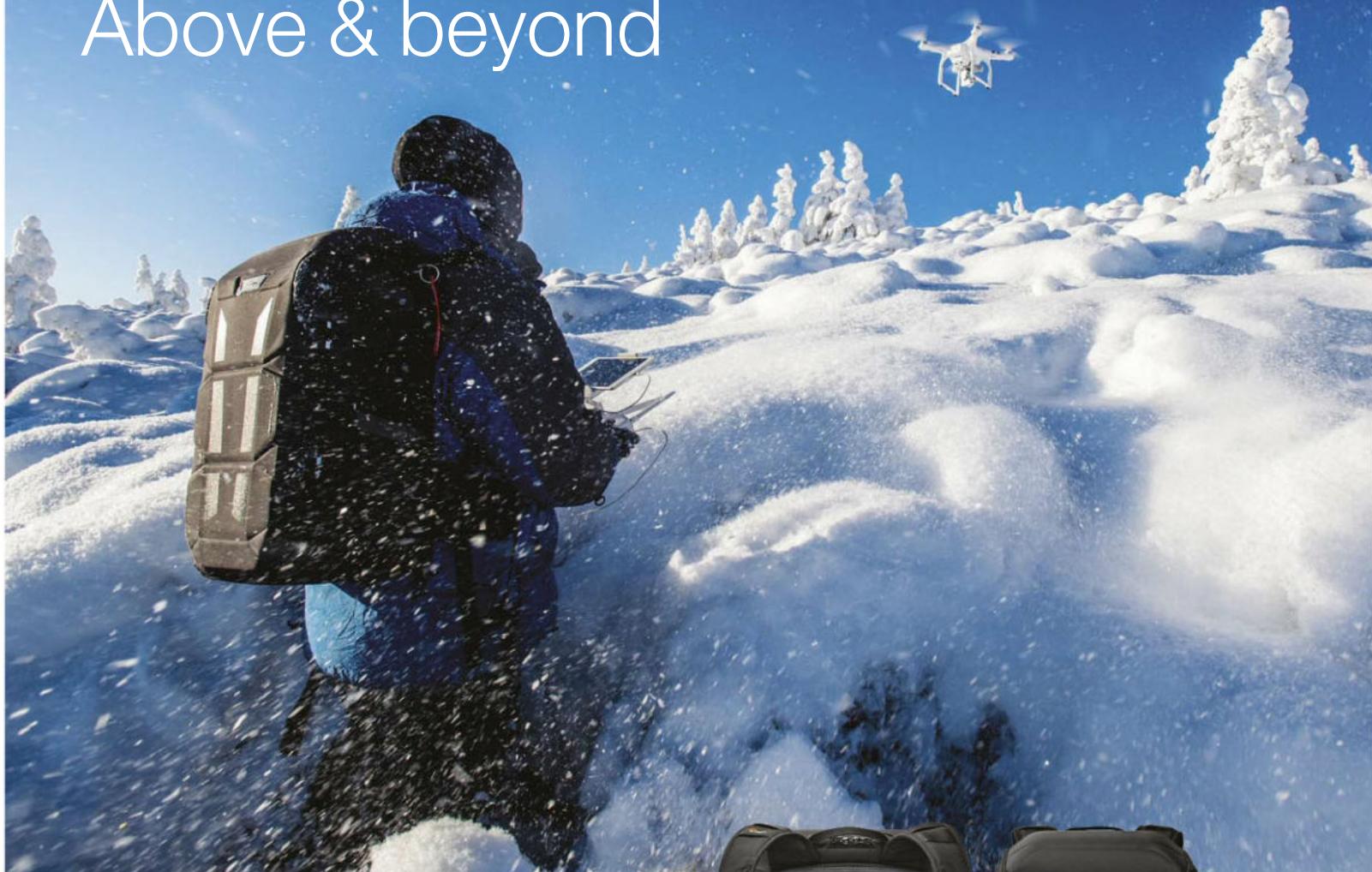
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At the heart of the image

WELCOME



In the not too distant future, the skies will hum with the sound of drones. It seems almost inevitable that we'll see flying robots whizzing around overhead working as couriers, traffic wardens, police officers and more. Right now, though, their work is a little bit more glamorous.

Scientists are piloting unmanned aerial vehicles (UAVs) into some of the most inhospitable corners of the planet and beyond.

Whether they're mapping the heart of a volcano or uncovering ancient Amazonian villages, these agile craft are launching a new age of discovery in which treasures are being found by fearless robots, rather than intrepid explorers. Check out the plucky drones on p34.

Meanwhile, astronomers also have a new tool to help them explore the heavens. In February, physicists announced that they had finally observed gravitational waves – ripples in the very fabric of space, predicted by Einstein 100 years ago. These waves will give scientists a new lens through which to observe the Universe. They'll let us see into the most powerful black holes and look further back in time than ever before. Find out what we could uncover on p54.

Finally, on 22 April, it will be Earth Day. There are loads of ways to get involved – visit earthday.org – but this year it got us thinking. Planet Earth doesn't have its own flag, so as a bit of fun, we asked scientists and designers to give us their thoughts on what could emblazon the planet's very own emblem. See their responses on p76.

Daniel Bennett, acting editor

IN THIS ISSUE



MICHAEL MOSLEY

The BBC science presenter looks at the lucrative free-from movement to find out whether gluten and lactose are really as evil as we are led to believe, or if we can tuck in to a guilt-free macaroni cheese. → p46



ZOE CORMIER

We've all typed in a Google search only to be greeted by some risqué images. But do we need to worry about the effect of porn on our minds? Science writer Zoe Cormier probes into the psychology to take a look. → p68



TIM RUFFLE

Tim Ruffle from Aardman Animations – the studio behind Wallace and Gromit and Shaun the Sheep – has turned his hand to something a little different this month by designing a flag for planet Earth. → p76

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FEATURES

Wonders of the drone age

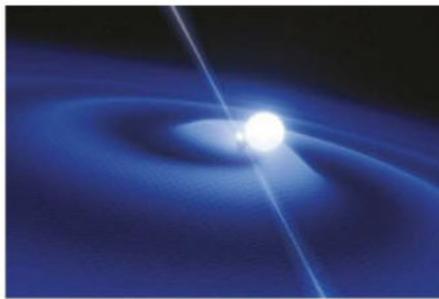
34 Unmanned aerial vehicles are helping us to explore exciting environments for the first time, including the Amazon rainforest and huge Vietnamese caves.

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Making waves

54 From gravitational waves and gamma ray bursts to black holes and neutron stars, deep space is home to some very strange phenomena.



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68 How does viewing pornography affect the brain and alter human behaviour?

A flag for planet Earth

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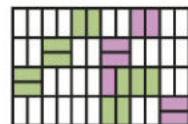
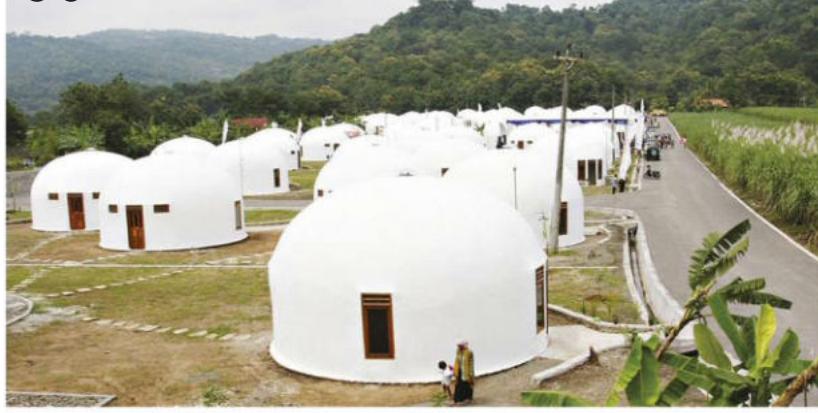
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TRAIN IN TROUBLE

LONDON,
UK

On the outskirts of London, a tower block has collapsed into Waterloo tube station. But no one has been injured. This is part of a training exercise that took place across four days in February and March to test how emergency teams will respond to a major disaster in the capital.

Using seven train carriages and thousands of tonnes of rubble, an entire tube station was recreated in a disused power station close to the Dartford Crossing. It was the largest such exercise ever carried out in Europe.

Firefighters, police officers and ambulance staff all took part in the training scenario.

More than 1,000 volunteer 'casualties' were covered in fake blood and given convincing injuries to make the scene as realistic as possible for the rescuers, who included specialist Urban Search and Rescue teams from around the UK.

But the drill – titled 'Exercise Unified Response' – wasn't just about rescuing trapped passengers. "An incident of this size affects everyone, from thousands of stranded commuters who can't get home, to distraught relatives who can't reach loved ones," says London fire commissioner Ron Dobson. "We are working with Transport for London, local councils and various voluntary organisations to simulate the wider and longer term impacts that any major disaster would have on the community."

PHOTO: JEREMY SELWYN/EYEVINE





REPLY

Your opinions on science, technology and BBC Focus

MESSAGE OF THE MONTH

Question time

In your March issue you ask "could your driverless car choose to kill you?" Is that moral dilemma really the point? Shouldn't we be asking whether we should build something that can intentionally kill the user? Who would want to use such a device? And how should one weigh up the different factors? Is the person the car is choosing to save – at the cost of your life – a father of two young children, or a stroke patient, or 98 years old?

Or let's assume the passenger of the car and the bike are both of the same sex, age and marital status with children of the exact same age. The only difference is that one is a blue-collar worker and the other the prime minister. Who should be killed then? Besides that, we do not all have the same values and morals around the world, let alone the same laws.

In my opinion, there is only one choice: the company who builds the car has to be liable for any damage. This should be the case whether it is between two autonomous cars or between one autonomous car and any other vehicle or person. And the coverage of that insurance is to be set at such a level to compensate for any medical and rehab costs but also for any costs to the family left behind. Only if the costs and consequences are placed on the shoulders of the companies, and not on the taxpayer, will the companies be acting responsibly.

Werner Reinberg, Shanghai

It's a fine idea, but I wonder whether insurance companies, or even their policy holders, will be happy to foot the cost.

Indeed, autonomous cars could make road accidents near-extinct – which will put car insurance companies under pressure to find money in other ways... – **Ed**

WRITE IN AND WIN!

The writer of next issue's *Message Of The Month* wins a pair of Momentum In-Ears, worth £89.99. These earphones are made of stainless steel, with no plastics used, to get the best sound out of a small package.



Werner Reinberg thinks that the autonomous car manufacturers should foot the bill for accidents

Media scare

Jamie Carter's article 'VR gets real' (February, p68) points out many advantages of the use of virtual reality, but doesn't mention the downside that should cause concern for many parents of schoolkids or students.

Battlestar Galactica spin-off *Caprica* featured teenagers visiting hedonistic virtual reality nightclubs. It is, I find, quite sobering to think that children and students could enter nightclubs and try for themselves the 'enjoyment' of drinking and drug-taking before physically doing it.

Yes, some people would argue that it's not actually real. But from pretend games come the opportunities for youngsters to 'learn' the dark side of VR and meet with undesirables.

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I know technology is here to stay, but how do we avoid an issue such as this?

Peter Carey, Portchester

⌚ It's unlikely that VR will be able to 'simulate' the enjoyment of alcohol or other drugs in the near future. But there are other risks. The immersion offered by VR is unparalleled, and to some, the escapism offered by VR could become addictive. – **Ed**

Ethics smethics

The ethical dilemma posed in 'the trolley problem' is nonsense. It is posed as a binary problem when it is a dynamic problem with multiple solutions depending on the actions of others. My initial solution is to de-rail the trolley by partially switching the points. One could shout a warning to the people on the track, or they may even notice the trolley and take evasive action. But these 'solutions' all depend upon the distances and dynamics of the evolving situation.

Tony Caporn, via email

The nuclear option

Your article in March's edition of the magazine raised some interesting points. The power supply system in the UK is established on a base load currently supplied by a mixture of gas, nuclear and some coal power stations. This is supplemented by extra generating capacity for peak times such as breakfast and 6pm. This is usually supplied by gas turbines, which can be switched on and off quickly. Although renewables are making a

contribution to our generating capacity, this can only be a small portion of our total needs. This is because renewables are unreliable, dependent as they are on wind speed and sunshine, which vary from day to day. The most reliable renewable is tidal power, but we don't have many estuaries that are suitable. Large scale energy storage is not currently feasible. If we are to reduce our carbon dioxide emissions as per our published target, the only option for the base load is nuclear or gas/carbon capture. As the latter isn't making much progress, then nuclear is the only option.

Dr Barry Culpin, via email

More optimism, please

After reading the piece by Robert Matthews on rubbish theories (February, p67), I felt the need to write in. Despite the opinions of Matthews and many others, to say there is no hope for understanding Alzheimer's is grossly incorrect. While progress has been slow, we actually understand a lot more about this disease than ever before. I gather that Matthews is not too familiar with Dr Aubrey de Grey's work surrounding Alzheimer's? Maybe he should familiarise himself with it and learn to be a little more optimistic and a little less negative.

Jessica Roberts, Brighouse

Tough cookie

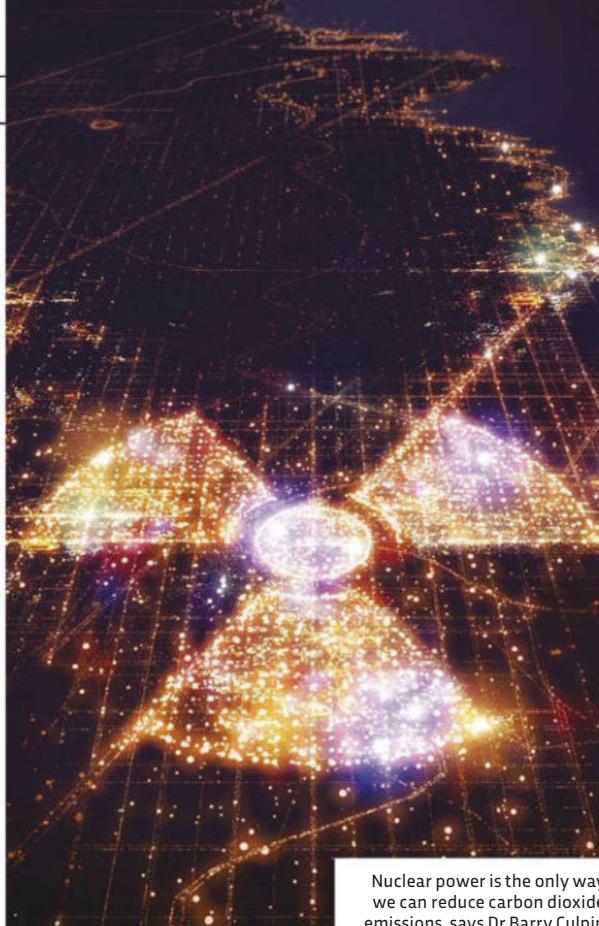
After reading all about the incredible resistance properties of tardigrades in your magazine (March, p23), I was wondering why modern society hasn't yet harnessed this amazing source of strength and created tougher aeroplanes? Or perhaps more importantly and pressingly, stronger linings for running shoes



Jessica Roberts thinks that Robert Matthews should take a look at the work of Dr Aubrey de Grey (pictured)



Could a pair of shoes made from tardigrades solve Robert Roemer's problem?



Nuclear power is the only way we can reduce carbon dioxide emissions, says Dr Barry Culpin

because I seem to keep wearing mine out every eight months or so! This in itself is a complete mystery to me, indeed even more so than the heralded strength properties of the tardigrade!

Robert Roemer, via email

Perhaps scientists need to investigate the incredible destructive properties of your feet, Robert? — Ed

OOPS!

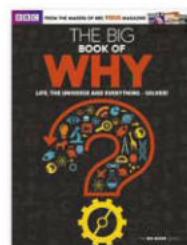
In the March issue, we said that two-stroke fuel is made with diesel and oil. It is actually made with unleaded petrol and two-stroke oil.

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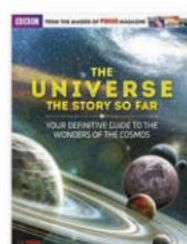
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THE UNIVERSE: THE STORY SO FAR

Barely a week goes by without some thrilling discovery about the Universe hitting the headlines. So we've compiled everything we currently know about the cosmos into *The Universe: The Story So Far*.

DISCOVERIES

DISPATCHES FROM THE CUTTING EDGE

APRIL 2016

EDITED BY JASON GOODYER

Stranded on Mars, *The Martian's* Mark Watney is forced to cultivate potatoes to survive



BOTANY

VEGETABLES GROWN IN MARTIAN SOIL

Crops harvested from a simulated Martian allotment hold clues to making agriculture on the Red Planet a feasible proposition

In hit sci-fi movie *The Martian*, stranded astronaut Mark Watney (played by Matt Damon) feeds himself by growing potatoes in soil from the Red Planet's surface.

Now, researchers from the Netherlands have replicated the feat using simulated Martian soil made from rock taken from Hawaiian volcanoes.

The team successfully harvested 10 different crops including tomatoes, peas, rocket and cress. The plants grew just as well as controls planted in regular potting compost.

"That was a real surprise to us," said researcher Wieger Wamelink. "It shows that the Mars soil simulant has great potential when properly

“ONLY THE SPINACH SHOWED POOR BIOMASS PRODUCTION”

“This is because we expect that first crop growth on Mars and the Moon will take place in underground rooms to protect the plants from the hostile environment, which includes cosmic radiation,” said Wamelink.

There is, however, one downside: the plants are not safe to eat. “The soils contain heavy metals like lead, arsenic and mercury, and also a lot of iron. If the components become available for the plants, they may be taken up and find their way into the fruits, making them poisonous,” Wamelink said.

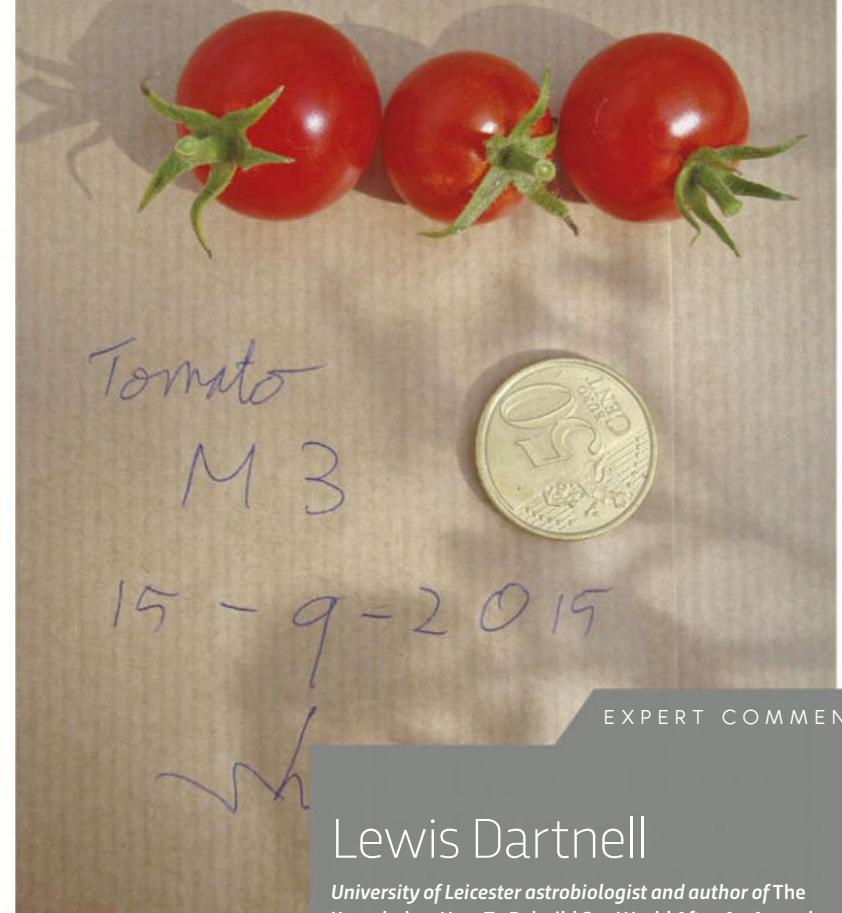
The Dutch team has now launched a crowdfunding campaign (visit their site at bit.ly/martian_meal) to finance a further experiment that will concentrate on producing food that’s safe to eat. They hope to begin the experiment in April; if the crops prove to be a success, they intend to invite funders to join them for a Martian meal made up of the harvested crops.



PHOTOS: WIEGER WAMELINK/WAGENINGEN UNIVERSITY X4

prepared and watered. Only the spinach showed poor biomass production.”

The plants were grown in trays filled with a mix of simulation soil, which was created by NASA, and freshly cut grass in a glass greenhouse and kept under constant temperature, humidity and light conditions.



EXPERT COMMENT

Lewis Dartnell

University of Leicester astrobiologist and author of The Knowledge: How To Rebuild Our World After An Apocalypse

“How much of a landmark is this result? These results from Wageningen University are certainly exciting. Being able to grow our own food will be a critical component of long term habitation on Mars – we’ll have to become space farmers! But we’re only just working out now what crop species might be best suited, and how to exploit ‘in situ resources’ using Martian water, nutrients and regolith [dust, soil and broken rock] rather than having to fly soil from Earth all the way to Mars.

How closely did the experiment mimic the real conditions on Mars? This particular experiment used a simulant for the Martian regolith, but then added lots of organic fertiliser in the form of grass clippings and manure, which of course wouldn’t be available on Mars. So it’d be important to demonstrate yields from a more realistic testing of an actual Mars mission, and possibly also under the sort of reduced air pressure found in an inflatable Martian greenhouse.

Does this mean agriculture would be viable on Mars on a scale large enough to sustain a colony? That’s certainly the hope! There’s still a lot of work to be done. The first crewed mission to Mars will probably be short term and take much, if not all, of the food they need with them, but in the long term this is exactly the sort of research that’s needed.

Does this mean there could be, or could have been, plant life on Mars? The short answer is no! Showing that Earth plants can survive in Martian soil, with added fertiliser and an Earth-like atmosphere, does not mean that plants could ever have evolved on Mars themselves. The environment on the Martian surface has been exceedingly hostile to life for a long time: freezing cold, dry, low atmospheric pressure and unprotected from ultraviolet radiation from the Sun. Hardy ‘extremophile’ bacteria might be able to survive such conditions, but not complex, multicellular plants.

ZOOLOGY

A STONE'S THROW FROM RITUALISTIC BEHAVIOUR

Chimps in parts of West Africa have been observed repeatedly hurling stones at specific trees – for no obvious reason

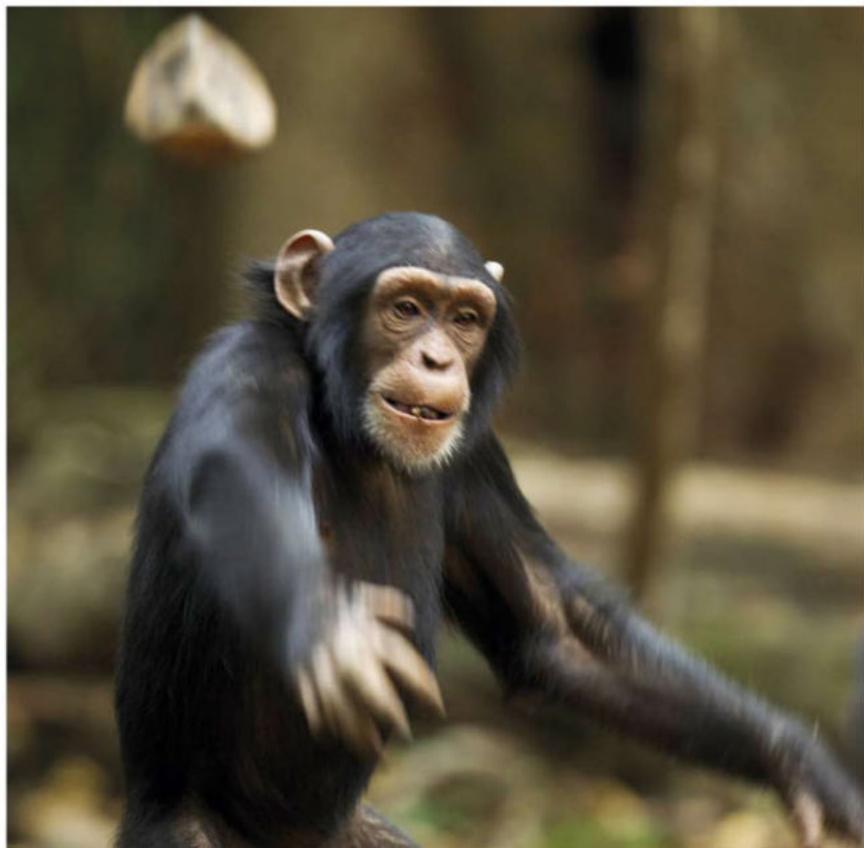
A team led by Hjalmar Kuhl and Ammie Kalan from the Max Planck Institute for Evolutionary Biology have captured footage of chimps throwing rocks at trees – behaviour that has perplexed researchers. A camera trap set up to record the primates' actions when no humans were present caught the film. Chimps have long been known to use tools (using stones as hammers to crack open nuts, for instance) but what's so puzzling about the stone throwing is that it has no clear purpose. And the behaviour is not observed in chimpanzee populations elsewhere.

"What we discovered wasn't a random, one-off event; it was a repeated activity with no clear link

to gaining food or status. It could be a ritual," said Laura Kehoe, a PhD researcher at Humboldt University of Berlin involved in the research.

Some have suggested the behaviour, which leads to piles of stones accumulating at the base of the trees, may be a way of marking territory; others have posited it as evidence of some kind of spiritual belief system, pointing out similarities with the construction of stone cairns by primitive tribes.

Whatever the answer, the existence of such 'ritual' behaviour that is specific to a given area indicates strongly that chimpanzee behaviour is more complex than was previously believed.



“THE
BEHAVIOUR
IS NOT
OBSERVED
IN CHIMP
POPULATIONS
ELSEWHERE”



Do these stone altars suggest that chimps carry out ritualistic behaviour?

IN NUMBERS

5–18g

The amount subjects in a study at the University of Illinois reduced their daily sugar intake by after replacing four drinks with plain water.

14,600

The number of Sumatran orangutans living in the wild, according to a new survey. That's 8,000 more than was previously thought.

7,080

The distance (in kilometres) migrated annually by some *Pantala flavescens* dragonflies, according to research carried out at Rutgers University Newark.

The hypothalamus (highlighted in yellow) may be the trigger mechanism that psyches you up for a fight

NEUROSCIENCE

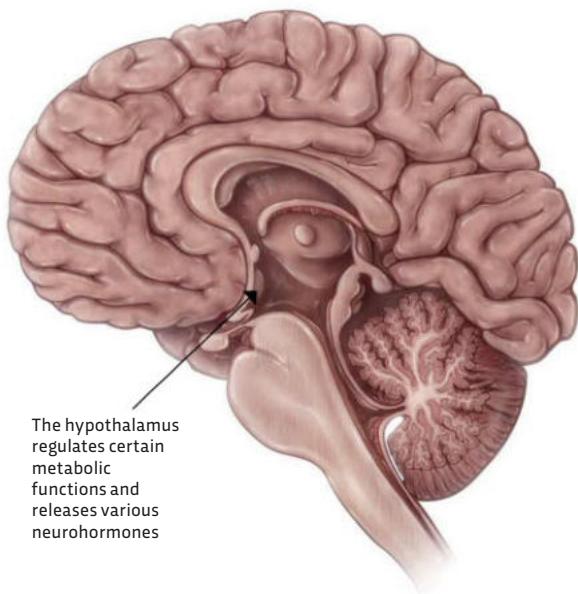
Brain region responsible for violent thoughts pinpointed

Before a human or another mammal commits a violent act, they will often experience a build-up of 'aggressive motivations' – and now a research team at the NYU Langone Medical Center believe they have worked out the exact spot in the brain where this build-up occurs. Their findings were published in the journal *Nature Neuroscience* on 7 March.

Using probes to study the brain activity in mice, the team found that before a group attacked smaller mice, there was increased activity in the ventrolateral region of the ventromedial hypothalamus, a part of the brain linked to sleep, hunger and body temperature regulation. Mice in whom activity in this part of the brain was suppressed didn't respond to the same stimuli in the same aggressive fashion.

Dr Dayu Lin of NYU Langone's Neuroscience Institute, who led the research, said: "Our study pinpoints the brain circuits essential to the aggressive motivations that build up as animals prepare to attack."

By better understanding how the impulse to engage in violence arises, it's possible treatments could be devised to prevent it – although Lin says this is currently only "a distant possibility".



IS EARTH SPECIAL AFTER ALL?

"Earth has violated the Copernican principle, which states that our planet is not in a favoured position"

BEHIND THE HEADLINES

A new cosmic inventory suggests the Earth may be completely unique. Graham Southorn asked Prof Don Pollacco, an exoplanet expert, what this means for Earth and the search for intelligent life

Scientists at Uppsala University in Sweden say they've created a 'cosmic inventory' of terrestrial planets. How did they produce it?

In a way it's quite straightforward. Scientists have already put a lot of work into understanding the history of galaxies, and we're beginning to understand the ways planets are arranged around different kinds of stars. What the Uppsala team has done is put the two things together. The number of planets [in the Universe] is dictated by the

numbers of stars and when those stars came into being. The rate of star formation has changed since the beginning of time, and so the team at Uppsala University looked at what would have happened to the planets that were being made in that time. It's all intimately tied up with the way galaxies evolve.

They estimate the mean age of terrestrial planets to be eight billion years, whereas Earth is only 4.5 billion years old. What does that tell us?

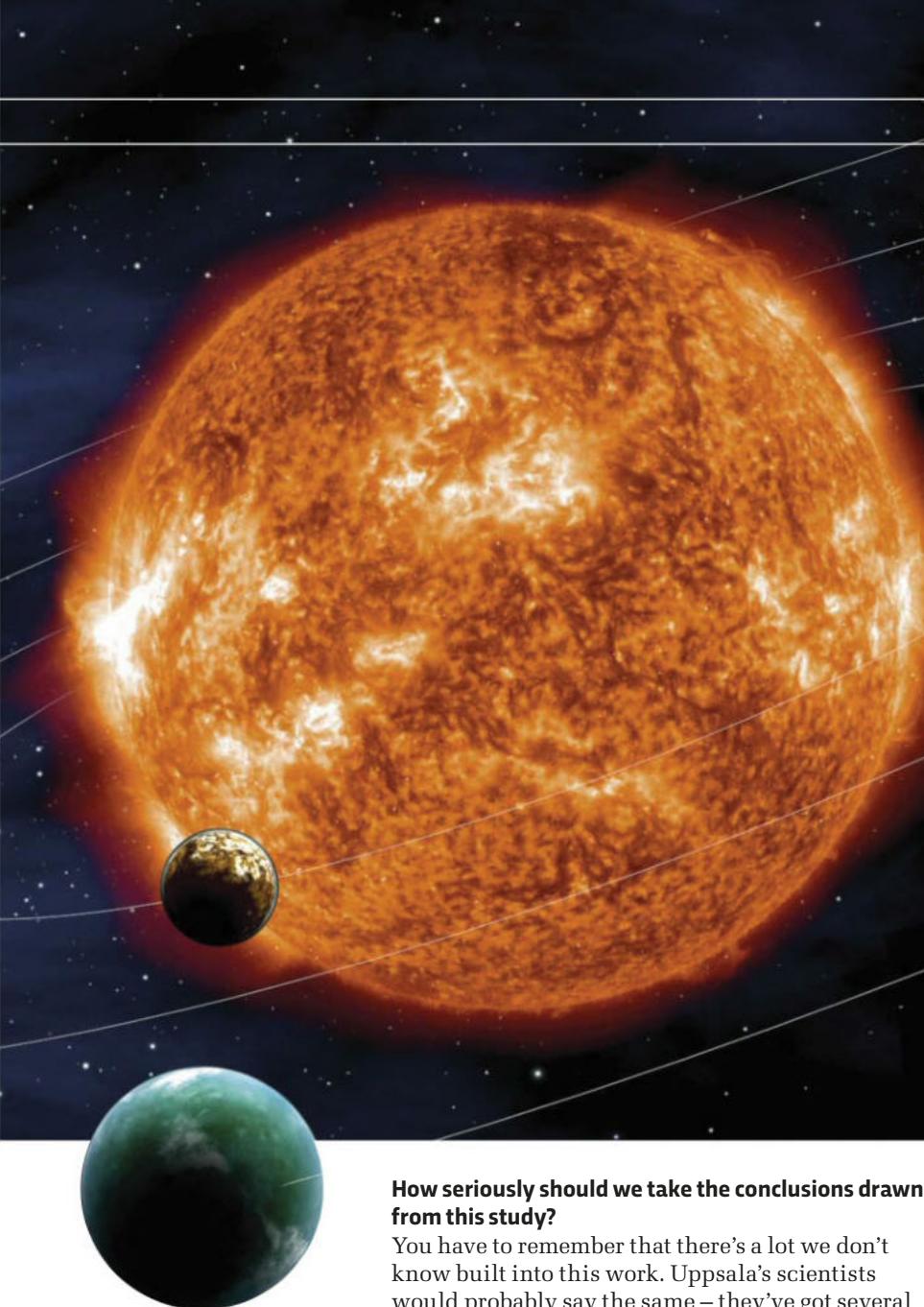
It tells us that the mean age of stars is a lot older than the Sun because most stars are in elliptical galaxies. Also, the 'typical terrestrial planet' is in a spheroidal galaxy with twice the mass of our spiral Galaxy...

If a typical location [for a terrestrial planet] is in a spheroidal galaxy, then you'd expect most planets to be in those galaxies. But if that is actually the case, Earth has violated the Copernican principle, which states that we are *not* in a favoured position.

Perhaps there's some unknown reason why spiral galaxies are preferred. If we aren't violating the Copernican principle, there must be a reason why life is evolving in galaxies like ours.

RIGHT: Nicolaus Copernicus's work led to the heliocentric model of the Solar System in which the Earth and other planets orbit the central Sun





How seriously should we take the conclusions drawn from this study?

You have to remember that there's a lot we don't know built into this work. Uppsala's scientists would probably say the same – they've got several pages discussing the errors. It's still very early days for this kind of study because it involves all the things we don't know about galaxy and planetary evolution.

ABOVE: The Uppsala study suggests the number of terrestrial planets is intimately connected to the number of stars

BETWEEN: With twice the mass of a spiral galaxy like the one seen here, a typical spheroidal galaxy would seem to be a likelier home to terrestrial planets



They say the prospects for finding life on other planets are better if we look closer to home rather than far away. Why is that?

It's because of the time it takes for an evolved society to come into existence. It's intimately connected with the ages of planets – as you look further away, back in time, the planets are younger. There's no point looking at the start of the Universe because a society hasn't had time to evolve.

THEY DID WHAT?!

Penguins made to run on treadmills

What did they do?

A team at the University of Roehampton trained eight king penguins to walk on a treadmill and filmed them as they waddled along.



And what did they do that for?

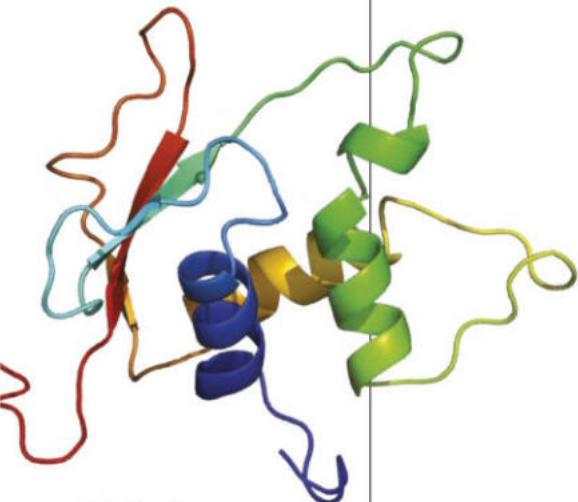
King penguins have to schlep several miles inland from the Antarctic coast in order to breed. As they have no means of hunting for food on land, they must first fill their bellies with fish to enable them to survive the breeding season. The researchers wanted to find out if the penguins' walking gait changed with body mass.

What did they find?

Tubby penguins tend to widen their gait to accommodate extra weight but they also sway more from side to side. This increased waddling gives them extra stability and helps prevent them from toppling over. They are still less sure on their flippers than trimmer counterparts, however. This potentially makes them an easier target for predators, the researchers say.



THE DOWNLOAD



IRF4

What's that? One of the robots from the new Star Wars film?

Not even close. It's the first gene ever identified with greying hair.

Tell me more!

A team at University College London has found that IRF 4 is involved with regulating the production and storage of melanin, the pigment that determines hair, eye and skin colour.

Does this mean an end to grey hair?

Possibly. Greying is caused by a lack of melanin in hair. Further study of IRF 4 could lead to new cosmetic applications that could switch off the mechanism that causes this.

Are there any... ahem, less vanity-led findings?

Yep. The gene could potentially be used as a model to study the biological processes involved in ageing, the researchers say.

NEUROSCIENCE

MATRIX-STYLE SKILL UPLOAD TO THE BRAIN ONE STEP CLOSER

Take the red pill: a team at HRL Laboratories in California has discovered that electrical brain stimulation can speed up the acquisition of skills.

In the classic sci-fi movie *The Matrix*, Neo (played by Keanu Reeves) is able to learn kung fu instantly thanks to a device that uploads the martial art directly to his brain. While the HRL technique can't quite replicate this, it was able to reduce the time trainee pilots took to learn to fly.

The team measured the brain activity patterns of six commercial and military pilots, and then transmitted these patterns into novice trainees as they learned to pilot an aeroplane in a flight simulator. To do this, they used a method called 'transcranial direct current stimulation' that passes a small current to the brain via a head cap embedded with electrodes.

The trainees who had undergone the brain stimulation technique showed improved piloting abilities and were able to land the plane

more smoothly compared to their unstimulated counterparts.

The method's potential to boost skills with brain stimulation may make accelerated learning commonplace, the researchers said.

"As we discover more about optimising, personalising and adapting brain stimulation protocols, we'll likely see these technologies become routine in training and classroom environments," explained lead researcher Dr Matthew Phillips. "It's possible that brain stimulation could be implemented for classes like drivers' training, SAT prep and language learning."

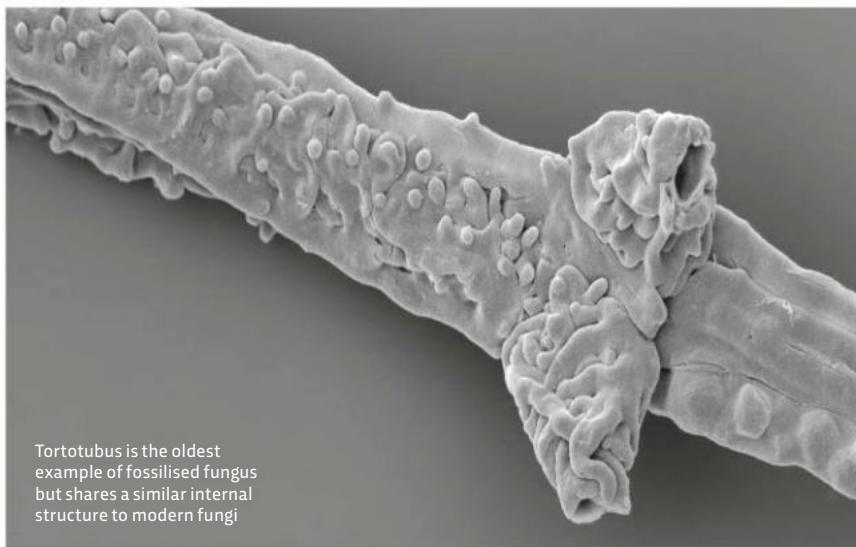
Sadly, this technology is not able to teach us how to leap from rooftop to rooftop or stop bullets in mid-air.



ABOVE: Caps with electrodes transmitted pilots' brain activity patterns to subjects
BELOW: Neo kicks butt in *The Matrix* after kung fu skills are uploaded to his brain



PHOTOS: MOVIESTORE COLLECTION



BIOLOGY

ANCIENT MUSHROOM MAY HAVE HELPED KICK-START LIFE ON LAND

*Meet *Tortotubus*, the 440-million-year-old fungus to which we may all owe our existence*

The earliest examples of land-dwelling organisms have been found on the Scottish Inner Hebridean island of Kerrera by researchers from the University of Cambridge. The tiny fossils of *Tortotubus protuberans* are smaller than the width of a human hair and played a key role in kick-starting the processes required for life to evolve on land.

"When this organism existed, life was almost entirely restricted to the oceans," said researcher Martin Smith. "But before there could be plants or trees, or the animals that depend on them, the processes of rot and soil formation needed to be established."

By reconstructing how the fungus grew, Smith was able to show that the fossils are made of mycelium, the root-like filaments that fungi use to extract nutrients from soil.

"This fossil provides a hint that mushroom-forming fungi may have colonised the land before the first animals left the oceans," said Smith. "It fills an important gap in the evolution of life on land."

PHOTOS: MARTIN SMITH; ILLUSTRATION: JAMES OLSTEIN

"BEFORE THERE COULD BE PLANTS OR TREES, THE PROCESSES OF ROT AND SOIL FORMATION NEEDED TO BE ESTABLISHED"



FASHIONISTAS

Researchers at Penn State University found that volunteers performed better at sports and maths tests when they thought they were using kit made by designer brands. The results mimic the placebo effect seen in medicine, they say.

SILVER SURFERS

A study at Mayo Clinic in the US has found that septuagenarian computer users are 42 per cent less likely to develop the cognitive issues that precede dementia.

GOOD MONTH

BAD MONTH

THE IMPATIENT

Patience is a virtue, and now researchers in Singapore have found it may help you live longer too. Impatient people's DNA seems more prone to ageing than that of their more patient peers.

YES MEN

Research by Australia's Monash University has found sycophants show more activity in areas of the brain associated with anxiety when they read statements they disagree with. This results in them giving in to peer pressure more easily.



BIOLOGY

WORLD'S OLDEST CHAMELEON FOUND IN AMBER FOSSIL

Getting stuck in tree resin is bad news for ancient critters but good news for today's scientists

A team in Florida has discovered 12 lizards fossilised in amber 100 million years ago. Among them is a well-preserved ancestor of modern-day chameleons that's the oldest ever found.

The fossils were originally found decades ago in Burma (now Myanmar) but remained in private collection until their recent donation to the American Museum of Natural History.

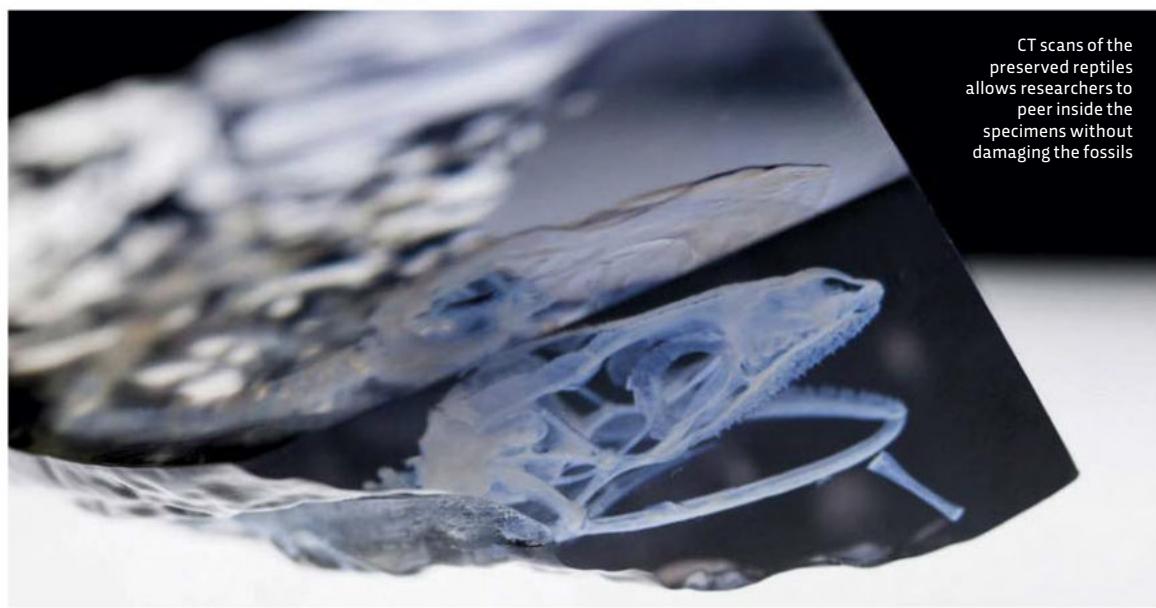
"These fossils tell us a lot about the extraordinary, but previously unknown, diversity of lizards in ancient tropical forests," said researcher Edward Stanley. "The fossil record is sparse because the delicate skin and fragile bones of small lizards don't usually preserve, especially in the tropics, which makes these fossils a rare and unique window into a critical period of diversification."

By imaging the fossils with a micro-CT scanner, the researchers could peer inside the amber without causing damage, allowing them to piece together detailed pictures of the reptiles.

"It's mind-blowing. Usually we have a foot or other small part preserved in amber, but these are whole specimens, claws, toe pads, teeth, even coloured scales," Stanley said.

The fossils shed light on exactly when many of the modern features of lizards appeared. For example, adhesive toe pads can be seen on the amber gecko indicating that this adaptation originated earlier. Similarly, the tiny chameleon has the projectile tongue seen in its modern counterparts but had not yet developed the body shape and fused toes we see today.

"USUALLY WE HAVE A TOE OR OTHER SMALL PART BUT THESE ARE WHOLE SPECIMENS"



WHAT WE LEARNED THIS MONTH

PLUTO MAY HAVE CLOUDS

Photos sent back from the New Horizons spacecraft following its flyby of Pluto last July show what appear to be hazy, cloud-like features in the atmosphere. Pluto was demoted to dwarf planet status in 2006. If confirmed, the finding could strengthen the case for it to be reinstated as a full planet.

'SIMPLE' FACES ARE CONSIDERED MORE ATTRACTIVE

A study at the University of Queensland has found symmetrical faces with no unusual features are perceived as more attractive. The effect is thought to be due to 'simpler' faces being easier for the brain to process.

GETTING TATTOOS CAN PROTECT YOU AGAINST COLDS

Maybe it's time to get inked. The body's stress response triggered by having multiple tattoos can lead to a strengthened immune system, researchers at the University of Alabama have found.

CHOCOLATE MAY MAKE YOU MORE INTELLIGENT

Break out the choccy! A 40-year study by researchers in New York has found that people who eat chocolate once a week perform better in memory and abstract reasoning tests.



COMPETITION

Calling wannabe science writers!

Do you think you've got what it takes to be a science journalist? Well now's your chance to prove it: the University of the West of England's Science Communication Unit is launching a writing contest in association with the Royal Institution and *BBC Focus*.

The competition is open to anyone who doesn't write for a living, and entries from bloggers and scientists are welcome. The topic is 'The next big thing in science'. To enter, write an article on that theme that's suitable for publication in *BBC Focus*.

The judges, who include the Royal Institution's Gail Cardew, IFL Science's Justine Alford and *BBC Focus*'s acting editor Daniel Bennett, will be looking for lively, well-researched, thought-provoking stories. Articles must be no longer than 700 words and previously unpublished. Only one entry per person will be accepted.

Entrants will be split into two age categories: 17 and under, and over-18. Winning articles will be published on the UWE and *BBC Focus* websites, and the winners will each receive a year's subscription to *BBC Focus*. The judges will select a winner and runner-up in each age group as well as awarding highly commended honours.

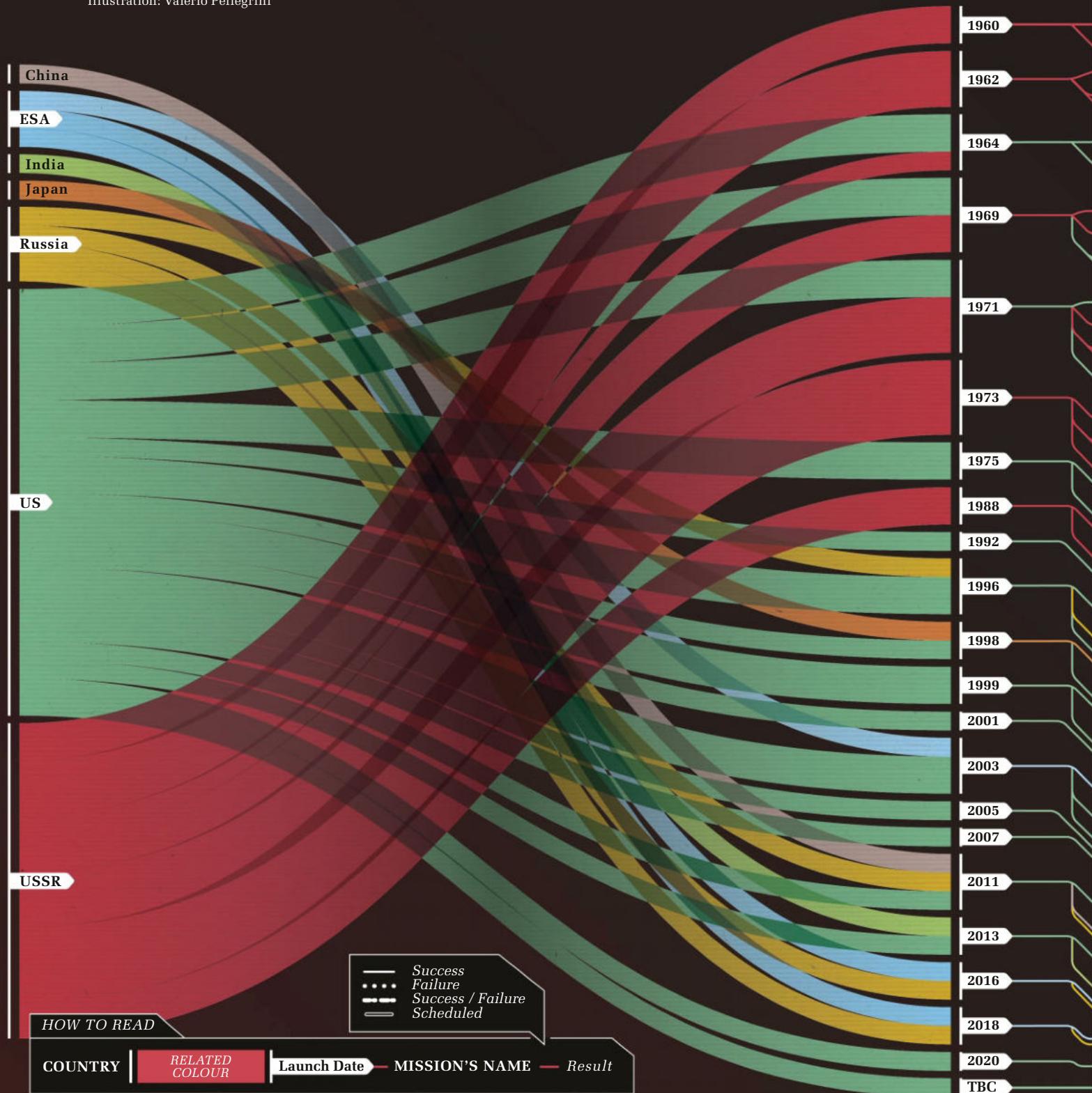
Winners in the over-18 class will have the opportunity for a week's work experience with *BBC Focus*, where they'll be able to develop their story for publication in the magazine. They'll also be able to attend a day-long science-writing course at UWE.

Entrants must provide their name, their age, and contact details on their entry, which must be received by 5pm on 24 June 2016. Entries can be posted to the Science Communication Unit, Faculty of Health and Applied Sciences, Frenchay Campus, Coldharbour Lane, University of the West of England, Bristol, BS16 1QY or emailed to writing.competition@uwe.ac.uk

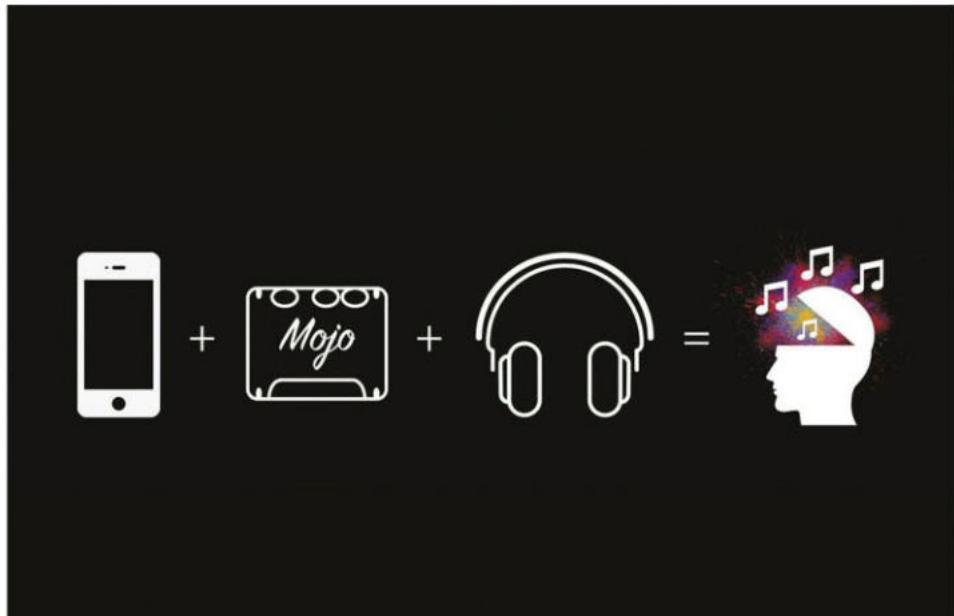
MAKING IT TO MARS

Illustration: Valerio Pellegrini

In mid-March, the ExoMars orbiter started its journey to the Red Planet. Today, there are five satellites in orbit around the planet, while four rovers are actively exploring its surface. But we haven't always been so good at reaching Mars, as this graphic shows...







AUDIBLE QUALITY

The rise of the smartphone means most of us are walking around with a versatile, hyper-powerful computer in our pocket. But there's one area in which the modern mobile is lacking

Once upon a time, it was hard work being a gadget lover. As well as the ubiquitous brick phone and charger, dedicated followers of the tech world could be found lugging around batteries, camcorders, pagers, cassette players, cameras and more.

These days it's all a little easier. Gordon Moore's prediction that microchip processing power would double every two years has held true, and it's brought about a revolution in portable tech. Smartphones can do everything those bulky gadgets could do and more, yet there's one crucial area the modern equivalents are found wanting: audio quality.

The quest for portability has seen manufacturers cut corners when it comes to digital to analogue converters (DAC) - the chip that takes the 1s and 0s that make up an audio file and translates them into audio. Good headphones can help,

but they can never make up for the loss of quality at such a fundamental level.

HELP AT HAND

But there is a solution. By using an external DAC like the Chord Electronics Mojo, you can restore your music to sparkling studio quality and hear it exactly as the artist intended. Simply connect the Mojo to your smartphone, plug in your headphones, and you're ready to go.

The ingenious bit of kit has a self-contained battery so it won't drain your phone, and its credit-card-sized body is portable yet reassuringly robust. The sound is simply fantastic, with a sampling rate of 786kHz, made possible by Chord's experience bringing their audio wizardry to giants like Abbey Road, Disney and The Royal Opera House. The Mojo is the easiest and most affordable way to bring that industry-leading clarity to your daily commute. Find out more at chordelectronics.co.uk/mojo.

WIN A CHORD ELECTRONICS MOJO

Fancy owning your own piece of Chord's flagship audio technology?

Simply head to bit.ly/ChordMojo and answer a simple question to be in with a chance of winning the £399 external DAC for yourself.

Mojo

• CHORD •

INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

APRIL 2016

EDITED BY RUSSELL DEEKS



ONE GIANT LEAP FOR GPS

A new system may bring the future of robots and self-driving cars into focus

The GPS satellite network is set to get a boost thanks to existing smartphone tech

GPS is ubiquitous these days. From geotagging our photos on Facebook to finding our way around using Google Maps, the ability to pinpoint our precise location has never been more desirable. There are more safety-critical applications for it too, like making sure self-driving cars, when they finally get here, won't drive us straight off a cliff. There are potential wider uses too – future leagues of robots will need GPS to navigate the world. So a new, more accurate GPS system that can measure your location to within mere centimetres accuracy is a welcome arrival. Or is it? •



Data from motion sensors in smart devices can now be used to enhance the accuracy of GPS

GPS, developed by the US military, works by triangulating your position on Earth's surface relative to three or more satellites. The first of the original GPS satellites launched in 1978 and the military system came online in the early 1980s. But the satellites alone could only detect your location to within 10m or so. Adding ground-based reference stations in the late 1990s brought that figure down to 1m. But now, a team at the University of California has combined GPS signals with data from the motion sensors typically found in smartphones to make the system accurate to within a couple of centimetres.

The approach isn't new: there have been attempts to implement such a system before but the need for large, powerful computers to crunch all the data quickly has held the technology back. Or it did until the University of California team came up with a formula capable of meshing the GPS and motion sensor data. The development of this algorithm will allow centimetre-accurate GPS to be incorporated into autonomous cars' navigation systems and smartphones.

"THE ALGORITHM ENABLES CENTIMETRE- ACCURATE GPS TO BE INCORPORATED INTO SELF-DRIVING CARS"

There are political implications tied to GPS to consider too. Europe, China, India and Japan are in the middle of building their own satellite navigation networks (see right). These systems, designed to reduce reliance on the US system, claim to be able to offer improved resolution over the current GPS network.

Whatever the long-term picture, though, the University of California team has managed to make pin-sharp GPS a reality, and for that they should be congratulated.

GPS: THE RIVALS

GALILEO

Currently under development by the European Space Agency and the European Union, the €5bn (£3.8bn) Galileo system (pictured below) will be accurate to one metre. The system will eventually consist of 30 satellites, of which just under half are already in orbit. It is due to reach initial operational capacity next year, with the network complete by 2020.

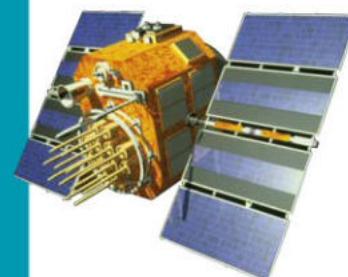


COMPASS

COMPASS, aka BeiDou-2, supersedes the BeiDou network, which provides satellite location services within China and the surrounding region only. Ten of its eventual 35 satellites are already in orbit and it should be fully operational by 2020, offering 10m resolution to civilians and 10cm resolution to the Chinese military.

GLONASS

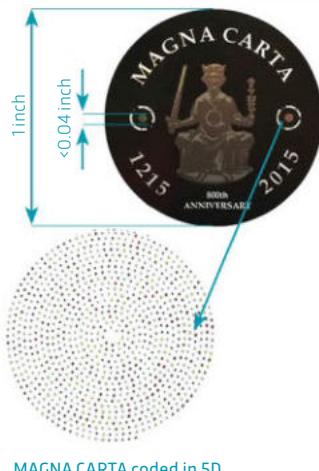
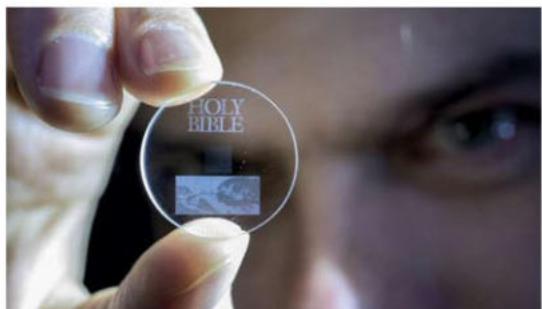
GLONASS (pictured below) is Russia's GPS. Construction of the satellite network began in 1976, and was completed in 1995. GLONASS has a resolution of 2m, and existing navigation systems, such as Google Maps, often use data from GLONASS as well as US GPS satellites to pinpoint your location.



IRNSS

Coverage by the Indian Regional Navigation Satellite System is limited to the Indian subcontinent. The network will eventually consist of seven satellites; five are already in orbit, the last two will launch this year and offer a resolution of 10m.

DATA



Indestructible 5D data disks created

A team at the Optoelectronics Research Centre at the University of Southampton have perfected a technique that allows data to be stored in five dimensions for billions of years.

The team has created disks that store data in three layers of nanoscale dots, separated by five-thousandths of a millimetre. The data is etched onto the disks using ultra-fast laser bursts that last only a tiny fraction of a second.

The dots' size and orientation, along with their position in the standard three dimensions, are what makes the disks '5D'. The dots modify the polarisation of light passing through the disk, enabling data to be read using an optical microscope and polariser.

The disks are robust enough to survive without degradation for 13.8 billion years (just over the lifespan of the Universe so far) at room temperature, and can handle temperatures of up to 1,000°C. They've been in development for several years: the Southampton team first demonstrated them in 2013 but the technology has improved greatly since then. In 2013 one disk could hold just 300KB of data – that figure has now risen to a whopping 360TB.

"This technology can secure the last evidence of our civilisation: all we've learnt will not be forgotten," said Prof Peter Kazansky of the Optoelectronics Research Centre.

COMPUTING

Cleaner, greener Wi-Fi

You probably don't think that Wi-Fi uses a lot of power, but sending and receiving data does require electricity – mostly to generate the analogue radio frequency (RF) element of a Wi-Fi signal. And as more and more 'always on' devices and cloud services play a role in our daily lives, the total power consumption of Wi-Fi systems is growing rapidly.

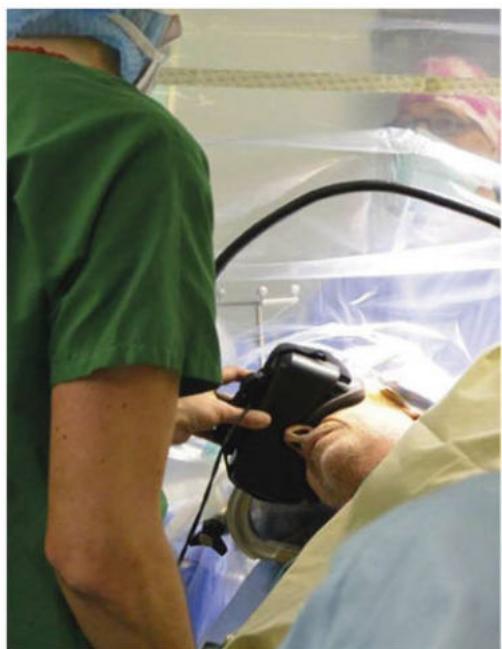
Enter 'passive Wi-Fi', a system developed at the University of Washington that's capable of making Wi-Fi transmissions that use 10,000 times less power. Rather than relying



on a network of devices each with its own RF transmitter, passive Wi-Fi uses a single RF element that's plugged into the mains to take care of all radio transmissions, which make up the biggest drain of power. Digital signals, which require almost no power, are then bounced between the devices at a rate close to current transfer levels.

MEDICINE

How VR can help brain surgeons



In January, surgeons at Angers University Hospital in France successfully removed a brain tumour from a cancer patient with the aid of virtual reality (VR) goggles.

Such operations often need to be carried out while the patient is conscious so surgeons can see which parts of the brain are functioning properly. However, as certain brain regions require specific stimuli to activate, it's not always possible to observe the brain carrying out particular functions while the patient is on the operating table.

By placing the patient in a VR environment, however, the French surgeons were able to replicate specific circumstances (in this case, bright objects in the patient's peripheral vision) that stimulated the brain in the region from which the tumour was being removed. "By controlling what the patient sees and hears, we can put them in situations that allow us to test certain connections that were not possible before," explains neurosurgeon Philippe Menei.

As a result, the tumour was successfully removed without impairing the vision in the one eye in which the patient still had sight. Had the medical staff been unable to test his vision during the procedure, it's likely he could have been blinded by the surgery.

WANTED!



CLIVE ALIVE

SINCLAIR ZX SPECTRUM VEGA PLUS

There've been several attempts to revive the much-loved ZX Spectrum in hardware form. But until now, none were designed by Rick Dickinson, designer of the original ZX computers. Endorsed by Sir Clive Sinclair himself, the Vega+ builds on the success of the

existing Vega by adding an LCD screen so you can play its 1,000 preloaded games on the move as well as hooked up to a TV. At time of writing, it had tripled its Indiegogo target and should start shipping in June.

[£100, retro-computers.co.uk](http://www.retro-computers.co.uk)

CAT SCAN

CAT S60

Caterpillar, the company that makes tractors and work boots, also makes super-tough smartphones, and its forthcoming S60 is the first phone with built-in heat vision. The phone features a thermal imaging camera from FLIR Systems, and is designed for use by the emergency services, as well as by tradespeople who might need to detect heat-loss around windows or identify over-heating components within a system, for example. The phone is waterproof to 5m, features a Snapdragon 617 octa-core chip and runs on Android Marshmallow.

[£649 \(£510 approx\), catphones.com](http://www.catphones.com)



NOT JUST FOR MUSOS

NAIM MU-SO QB

The latest addition to Naim's Mu-So range of wireless audio devices is the Mu-So QB. This combi amp/speaker system uses 32-bit digital signal processing, pumps out 300W of sound via five speakers and is compatible with all leading streaming services and protocols, including Bluetooth, AirPlay, UPnP, TIDAL and Spotify Connect. It also offers USB, optical and 3.5mm analogue inputs for hooking up external sources, can be controlled from your smartphone, and has internet radio and an alarm built-in.

[£595, naimaudio.com](http://www.naimaudio.com)



BETTER BRUSHING

ORAL-B GENIUS

Oral-B has unveiled a new 'smart' toothbrush that monitors your dental hygiene routine. Using built-in motion sensors and your smartphone's video camera, the Genius measures variables such as the amount of pressure applied and the time spent brushing particular areas, and provides feedback via an accompanying app. The brush will also automatically adjust its speed to compensate for any inadequacies in your brushing technique. It's expected to go on sale this summer.

ETBC, oralb.com



One
remote to
rule them
all

E, THAT'S CLEVER

SONY HUIS

Already available for pre-order in Japan, the Sony Huis (developed via Sony's own crowdfunding platform First Flight) takes the well-established concept of the universal remote and gives it a twist by using an e-ink touchscreen. This dramatically reduces the handheld's power consumption while helping to keep the interface clean and uncluttered. Controller setups for popular devices can be downloaded from the web, or you can create and share your own. No word yet, though, as to whether it'll reach the UK...

\$250 (ETBC), sony.com

A SMARTER SMARTWATCH

I.AM+ DIAL

Available exclusively to Three customers and created by will.i.am's technology start-up i.am+, Dial is a smartwatch with a twist. While most smartwatches are essentially just interfaces for your phone, Dial has its own SIM card slot and enables the wearer to make and receive calls, play music and text – no phone required. It's also got its own Siri/Cortana-style AI assistant, Aneeda. Could this be a game-changer in the wearables sector? Time will tell!

ETBC, three.co.uk



APP FEED



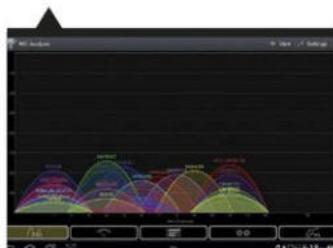
ReactionFlash

This app features over 250 named chemical reactions in flashcard form, and features a quiz mode to test your knowledge. *Free, iOS*



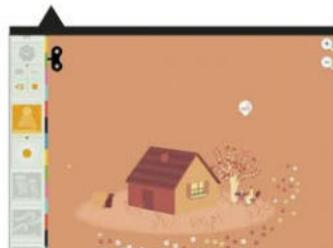
Wi-Fi Analyzer

Wondering which Wi-Fi channel you should switch to if your Wi-Fi's being unreliable? This app tells you... *Free, Android*



Weather by Tinybop

A great app for young kids that lets them tweak temperature and other variables in a cartoon world, and shows how it affects the weather. *£2.29, iOS*



Performance without compromise



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- Wireless as standard
- **Windows 10**
- 3 Year Standard Warranty

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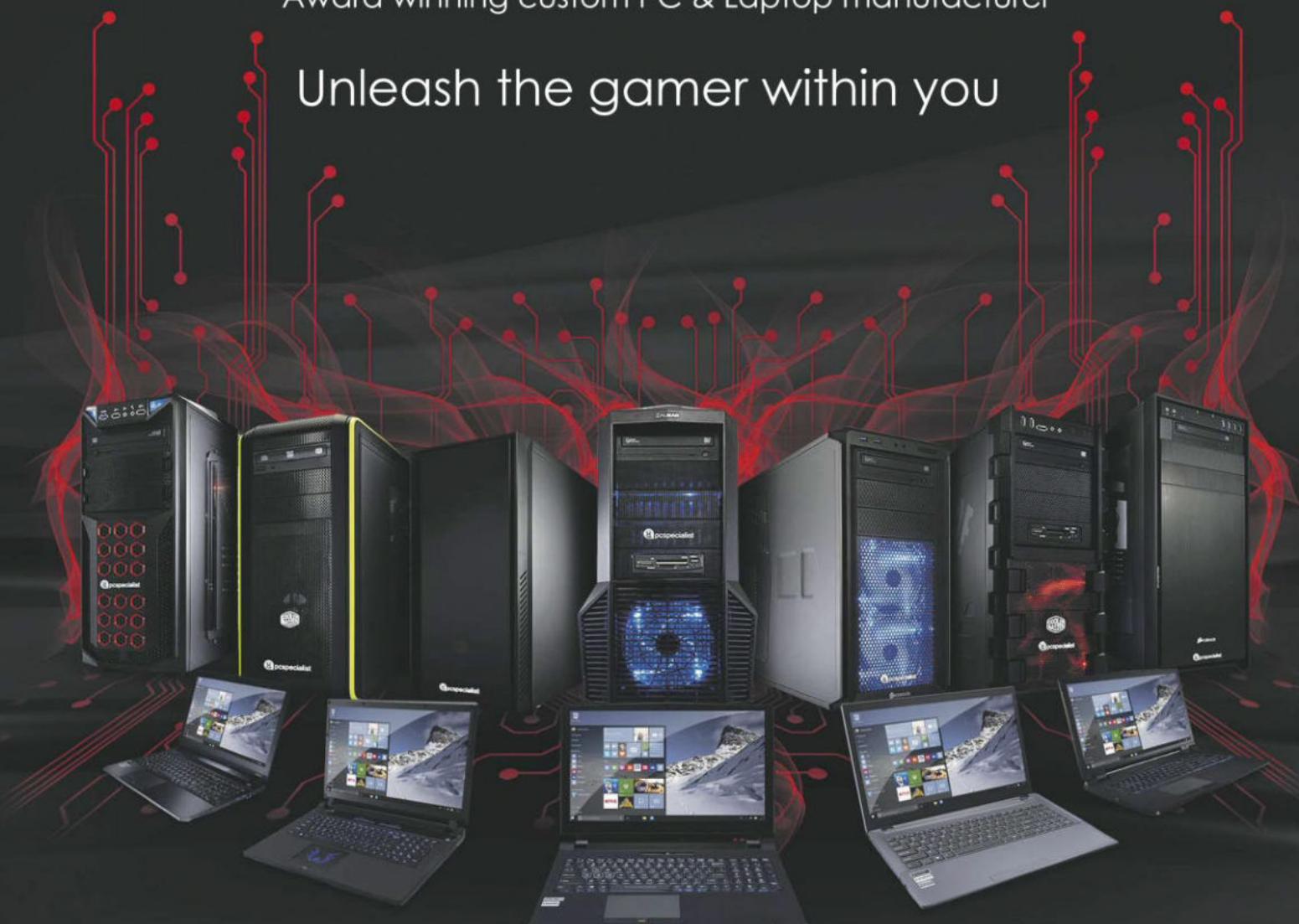
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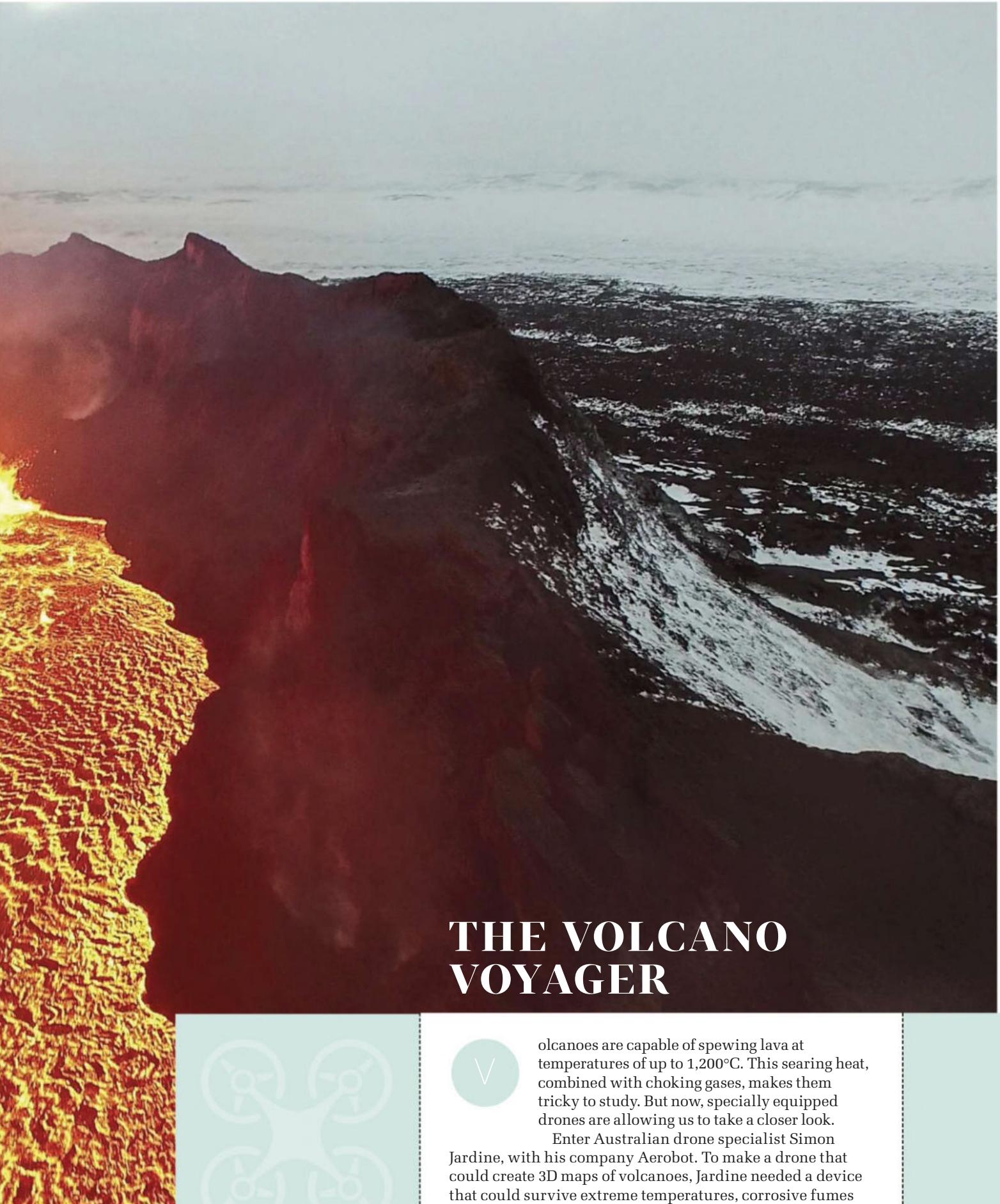
WONDERS OF THE DRONE AGE

A new wave of unmanned aerial vehicles is spreading across the world, discovering ancient civilisations, mapping caves and plunging into the hearts of volcanoes

Words: Luke Edwards



A drone braves the searing heat of an erupting volcano to capture 4K footage



THE VOLCANO VOYAGER

V

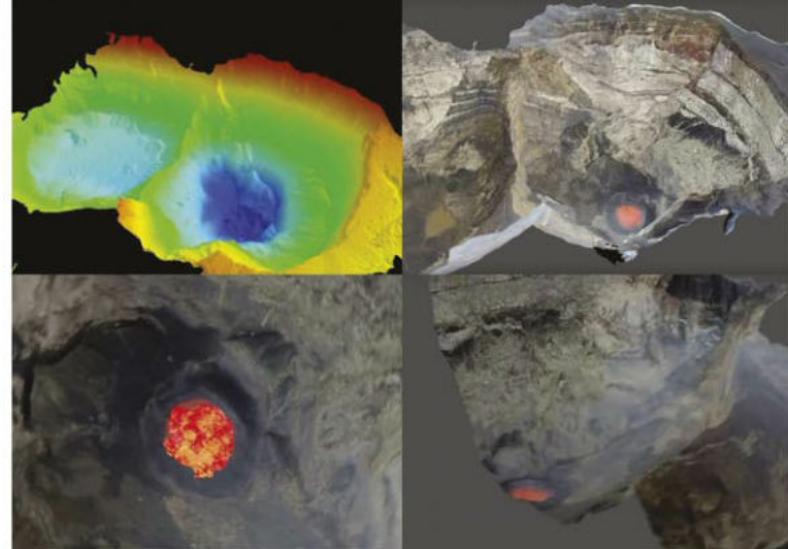
Volcanoes are capable of spewing lava at temperatures of up to 1,200°C. This searing heat, combined with choking gases, makes them tricky to study. But now, specially equipped drones are allowing us to take a closer look.

Enter Australian drone specialist Simon Jardine, with his company Aerobot. To make a drone that could create 3D maps of volcanoes, Jardine needed a device that could survive extreme temperatures, corrosive fumes and spinning winds. ➤

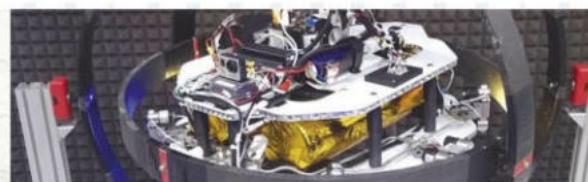


It was no easy feat. In order to map Vanuatu's Marum Crater, Jardine and his team lost several drones and cameras. The prolonged exposure to acidic clouds crippled electronics, while the shifting hot and cool air sent at least one drone smashing into the crater wall. Eventually, by using DJI Phantom drones and GoPro cameras, rendered via Pix4Dmapper, the team virtually recreated the crater (pictured right).

After paving the way into this new frontier, more drone volcano footage has emerged. Drone specialist and photographer Eric Cheng recently acquired some stunning 4K shots of active volcanoes in Iceland at the point of the biggest eruption in 200 years. His team flew two DJI Inspire 1 drones through buffeting thermals to capture the active volcano as never seen before. They even landed one on the lava flow – for science, of course...



The Marum crater is 420m deep and 1km wide

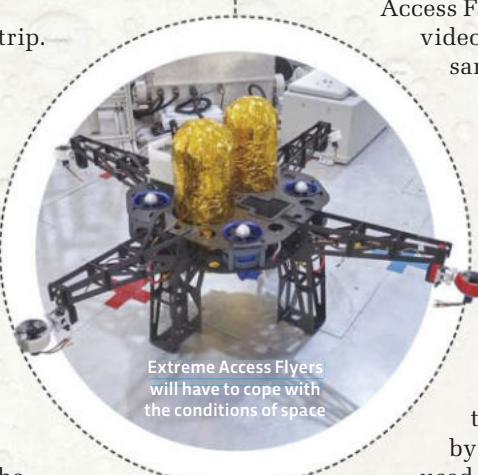


THE MARS EXPLORER

The Red Planet has a thin atmosphere and surface temperature averaging around -63°C, making it far less welcoming than some of the most inhospitable places on Earth.

Getting to Mars requires a tough trip. Astronauts would be exposed to incredibly long periods of space travel, the effects of which are still unknown. But we've still got plenty of time to carry out the required research, as humans are not scheduled to set foot on the red dirt until 2030.

Despite a lack of human explorers, Mars has already been mapped so accurately that there are Ordnance Survey maps available of 3,672 x 2,721km of the planet's surface. This is thanks to the data sent back by NASA's rovers. However, like all wheeled vehicles, the rovers have limited capabilities, especially when faced with walls angled at 30° or more. Drones do not have such limitations.



Extreme Access Flyers will have to cope with the conditions of space

NASA has already developed a drone that can cope with the atmosphere on Mars as well as conditions in outer space. These 'Extreme Access Flyers' won't just snap images and video, but will also collect actual samples from other planets.

While on the planet, the flyers will use quadcopter blades and ducted fans. But if they're needed in a zero gravity situation they can turn on cold gas thrusters. The plan, in the future, is to run the drones on propellants made from resources that can be found on distant worlds.

As is the case with a lot of technological advancements made by NASA, these creations could be used on Earth too. Imagine a site of heavy toxins, such as an area of high radiation, being studied by drones, or the first responders at a disaster being drones. That's already becoming a reality. All hail our drone saviours.



THE POLAR PILGRIMS

The North Pole is one of the most remote places on the planet. Despite the harsh environment, there is contention about ownership as there could be rich natural resources beneath the ice. To ensure its presence in the Arctic, the Canadian government has started working on drones capable of surviving the conditions.

Explorers have died in the sub-zero temperatures of the most northerly point on the planet, and normal drones would likely suffer the same fate. One of the major issues to overcome, if drones are going to explore the Arctic, is direction. At the Earth's polar tip the use of GPS is difficult. For drones to successfully navigate in the region, there needs

to be a 'crown' of satellites in the right positions to establish locational data.

Once navigation is solved, the drone then has to survive the cold. At temperatures of around -40°C, the reactions that batteries rely on slow to snail's pace. But it's not just chilly temperatures that stop flight – fog is a barrier too. In the Arctic, clouds and fog can undergo structural icing. That means that the water droplets crystallise on impact. Needless to say, that's a problem for a drone's spinning rotors.

Larger planes and helicopters can survive this as they are big enough to carry de-icing kit. This just isn't an option for a smaller drones.

The work of the Canadian government is still in its infancy but it currently looks like drones will act as assistants to manned missions. These could find the fastest way around a landmass, saving time, resources and potentially even lives.



Canada is researching drones that can navigate around the North Pole and survive sub-zero temperatures





Near the South Pole, the United States Antarctic Program has been trialling drones to map the changing sea ice. The UAV that took this picture was paired with an autonomous sub below the ice. This allowed a team to produce a photo mosaic of an ice field out of 500-1,000 images



PHOTO: AG EAGLE UNMANNED AERIAL SYSTEMS, RYAN DEBOODT

THE STORM CHASER

Tornadoes are one of Hollywood's favourite types of weather. Twisters take unpredictable paths, tear entire houses out of the ground and toss trucks around like they were child's toys.

Until recently, human storm chasers had to get close enough to a tornado to insert their measuring equipment by hand. But these storm chasers may not need to risk their lives for much longer. Drones could take over, leaving scientists to take up surfing instead.

A US-based team called The Sirens Project are carrying out experiments using fixed-wing drones to drop probes into tornadoes.

"Twisters take unpredictable paths, and toss trucks around like they were toys"

The decision to pick this type of drone was based on its ability to remain in the air for longest, hold stable flight in high winds and achieve the 160km/h (100mph) target speed needed to punch into a tornado. But getting the drone into the tornado is half the battle – then they need to get the data out.

DroneDeploy is a company that has created a remote recording and transmitting device capable of surviving inside a tornado. This allows for an internet-based connection with the drone, on top of the telemetry hardware built into the wing, but also helps to find it after its dance with the elements is over – and it's likely left broken.

This unit also allows for control of the drone from anywhere in the world via the internet. So if tornado chasers want units set up at multiple locations, then that's an option. More data collection means more early warnings, which means safer humans.

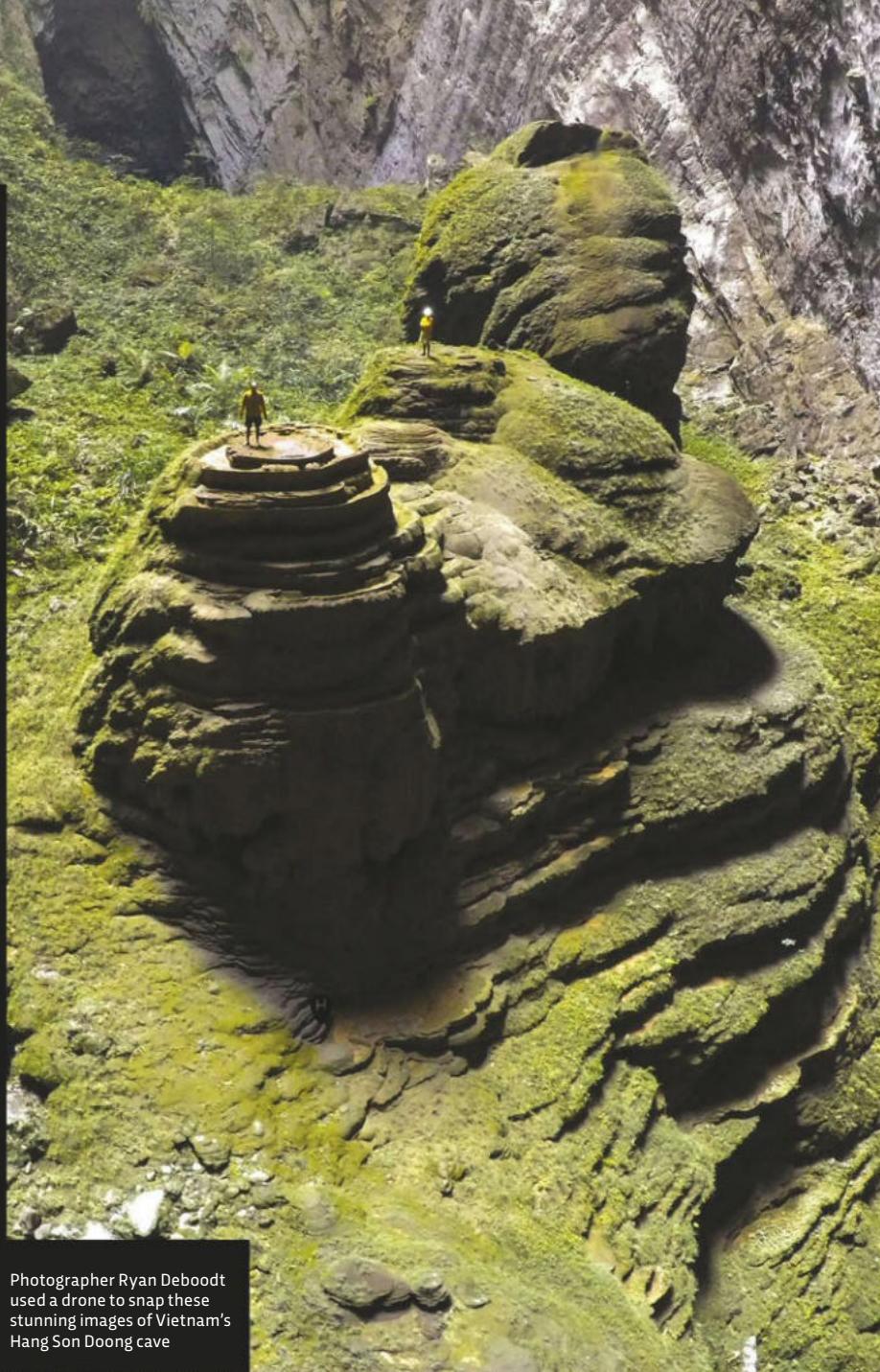
THE CAVE DWELLER

Vietnam's Hang Son Doong cave is enormous, and the prospect of mapping it is daunting. Its main passage is over 5km long, 150m wide and 200m high. Despite its incredible size, the cave was only discovered in 1991. The Cave of the Mountain River, as its name translates to, was stumbled upon by a local man after he heard the whistling of wind and the roar of its river. Until then, the perilously steep descent of the entrance had kept humanity at bay.

At some point the roof of the cave collapsed, leaving two large holes that let in sunlight. Trees and other vegetation have flourished in these sunny spots, making the cave look almost inviting. But climbers wanting to explore and map the cave came across some tricky obstacles. One individual who entered the cave early on described climbing 6m blades of limestone to circumnavigate the 150 networks of connected caves. They were ultimately stopped by a 60m wall of muddy calcite.

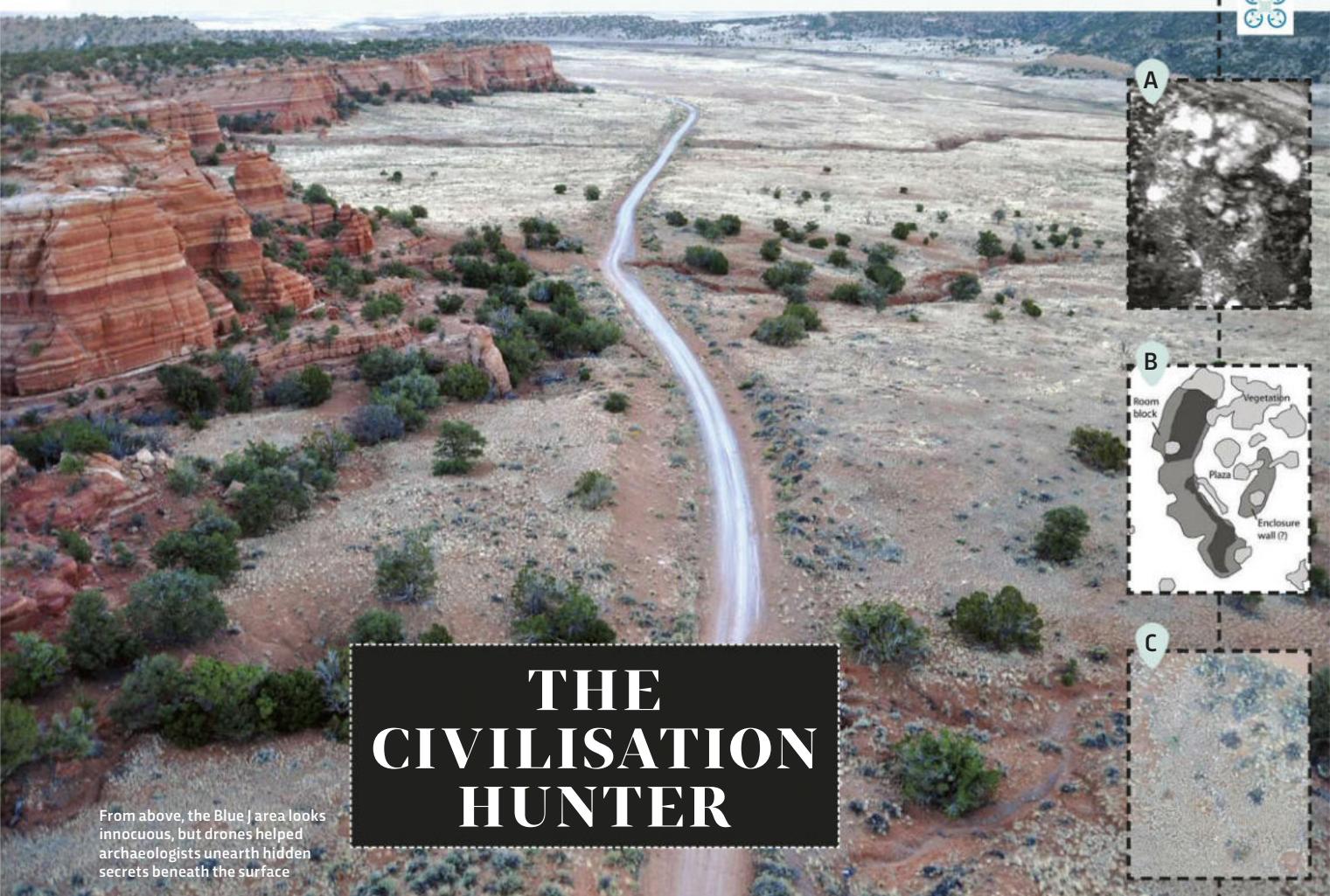
Time for the drones. Beijing-based photographer Ryan Deboodt sent his DJI Phantom II drone equipped with a GoPro Hero4 into the cave's depths to get a better look. He successfully managed to snap clear and wide-spanning views of the cavern. The ability of drones to move freely at speed highlights just how much more adept they are at exploring than humans – Indiana Jones included.

From August, heavy rains in Vietnam cause river levels to rise, making the caves largely inaccessible for humans. But for drones it's year-round open season.



Photographer Ryan Deboodt used a drone to snap these stunning images of Vietnam's Hang Son Doong cave





THE CIVILISATION HUNTER

From above, the Blue J area looks innocuous, but drones helped archaeologists unearth hidden secrets beneath the surface

Humans have lived in the Amazon basin for more than 13,000 years. In a bout of irony, the destruction of the Amazon rainforest has breathed new life into our understanding of ancient civilisations.

Deforestation has revealed over 450 geoglyphs – patterns left in the ground by former civilisations. These patterns could reveal if societies prior to the 1490s were small bands of hunter-gatherers and shifting cultivators, or more complex civilisations.

The problem standing in the way of improving our understanding is about 5,500,000km² of thick rainforest. Covering that on foot, which is about the only way to get through the dense growth, would take lifetimes. When you take into account the potential diseases, attacks by the likes of jaguars, alligators and snakes, plus dramatic weather, one life per person might not be enough. This is where drones can help.

One project, led by UK scientists, employs robotic

planes to fly over the Amazon. The drones are equipped with a LiDAR and multispectral sensors, which are able to effectively see through the dense canopy of leaves and branches that makes up the rainforest ceiling. The LiDAR works by bouncing light off objects to build an image. Throw in some algorithms to factor in light reflecting off the leaves and you're left with a pretty clear image of what lies within the forest.

This isn't the only place where old civilisations are being revealed by drones. A 1,000-year-old Native American settlement dubbed Blue J was recently discovered in the desert of New Mexico. By flying a drone equipped with infrared cameras, archaeologists

were able to see through the vegetation to paint a picture of the former civilisation beneath. By comparing drone images, archaeologists are now able to recognise varying materials so they can determine where to dig more accurately than ever. Watch out hidden cities, you're about to get spotlit.

"The drones are able to see through the canopy of leaves and branches"

ABOVE: Thermal images from Blue J (A) can be used to create an interpretation of the region (B) far more effectively than a standard photo (C)



THE BORDER DEFENDER

One of the least-travelled nations on the planet is North Korea. The strict communist regime stops the country's residents from leaving. Getting in or out of the country is risky.

North Korea and South Korea have been in a state of armistice since 1953. The two nations lay claim, despite its Demilitarized Zone name, to the world's most heavily militarised border. This area stretches for 250km (160 miles) and is 4km (2.5 miles) wide. It is heavily guarded on the surface and has been penetrated by underground tunnels on numerous occasions. But now drones are leaving North Korea, apparently to spy on their southerly neighbours.

In response, South Korea is researching drone-killing bots. Their mission is to search, locate and disable other unmanned aerial vehicles. Currently, automated tracking weapons such as missiles won't lock onto things as small as drones, so it falls to other drones to stop them.

The future could see drones versus drones on the battlefield, as smaller guard drones defend larger attack drones. The Dutch company Delft Dynamics has shown off a drone with a cannon that can fire a net over target drones, disabling and grounding them.

While a future of drone warfare is a worrying one, at least it'll mean fewer human casualties, right?



Drones have sneaked over Korea's heavily militarised DMZ

Dutch police are using birds of prey to disable drones

THE DRONE KILLER

Drones are fast becoming the bad boys of the skies. They have committed airborne crimes such as smuggling phones and drugs into prisons. On top of that, there are fears terrorists may start using drones. Plus, there have already been a number of near-misses at UK airports, in which drones have had close calls with aeroplanes. They have become enough of an issue for the UK government to start looking into ways of stopping the felonious flyers when needed.

So what better way to stop a man-made drone than with one of Mother Nature's perfectly evolved predators, the eagle?

Police in the Netherlands have already trained eagles to pluck pesky drones out of the skies. While some animal activists consider this a risky initiative because rotor blades are potentially dangerous, London's

Metropolitan Police is still considering using the birds of prey.

Drone laws are still not set in stone, but some rules are already in place. The UK Civil Aviation Authority (CAA) says that a camera-equipped drone must not be flown within 50m of congested areas or large groups of people, while commercially flown drones must have permission from the CAA. Meanwhile, the USA's Federal Aviation Administration states drones must not be flown within 8km (five miles) of an airport. 

Luke Edwards is a technology and gadgets writer.

DISCOVER MORE

 Listen to an episode of BBC Radio 4's *Moral Maze*, presented by Michael Buerk, discussing the morality of drone attacks at bit.ly/drone_attack



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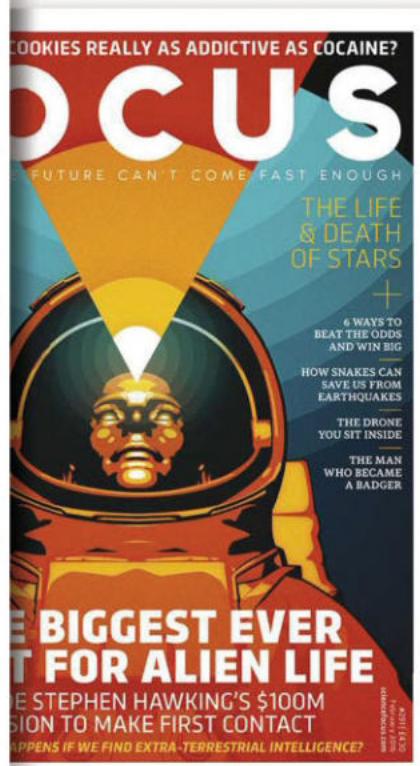
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THE ALLERGY FALLACY

For some, diving into a bowl of cereal each morning can lead to flatulence, vomiting and even an early death. But is there anything for the rest of us to gain from shunning gluten and lactose in the name of health?

Words: Dr Michael Mosley



PHOTO: KIRILL MAKAROV/DREAMSTIME



Don't miss Michael Mosley and his team of physicians in new episodes of *Trust Me, I'm A Doctor* - out later this year.

U

nless you have been living in a cave, existing on a paleo diet, you must surely have heard or read about the alleged twin dangers of gluten and lactose. Thanks to celebrities such as Gwyneth

Paltrow and Miley Cyrus, who have been pushing the miraculous benefits of gluten-free, dairy-free diets, supermarket shelves are now heaving with 'free-from' products. But is the growing free-from movement also free from facts? Time, I think to separate the wheat from the chaff.

Let's start with gluten, as the gluten-free bandwagon in the US is now worth an estimated \$4.2bn (£3bn) a year and growing fast.

Gluten is found in grains, such as wheat, barley and rye. If you've ever made bread then you know that when you mix wheat flour with water it produces a sticky mess. It's the gluten in the wheat flour that produces the stickiness as well as adding

elasticity to the dough, which helps it rise during the baking process.

We've been eating wheat for thousands of years, but it's only recently that people have got really worried about gluten (thanks, Gwyneth). So is gluten intolerance real, or is it just a passing fad?

CEREAL KILLER

At this point I have to declare a personal interest. One of my nieces has coeliac disease, the most severe form of gluten intolerance. It affects around 1 per cent of the population and is an autoimmune condition. What happens is that your immune system becomes sensitised to gliaden, a protein in gluten. When you eat gluten your immune system will not only attack these molecules, but also the lining of your gut. This results in inflammation, with common symptoms including bloating, diarrhoea, constipation and weight loss. You may also become anaemic due to blood loss. ☕



My niece first started to show symptoms when she was around three years old. She was tired, frail, off her food and generally lethargic. She was living in Paris at the time and a paediatrician assured my anxious brother that these symptoms were all down to sibling rivalry. My sister-in-law had recently given birth to another girl, so their doctor decided – for reasons best known to himself – that no further investigations were needed. Fortunately my wife, who is a GP, persuaded my brother to push for further testing, which revealed she had coeliac disease.

Coeliac disease is relatively common and easily missed. According to some studies up to 80 per cent of people with coeliac disease don't know that they have it. The only real way to find out is to have a blood test (where doctors look for antibodies) or to have a biopsy of your small intestine.



Gluten

is made up of hundreds of different proteins, the most important being gliadin and glutenin. It is the gliadin protein that causes the majority of problems, leading to intolerances. Gluten is found in wheat, barley and rye, though it is also present in soy sauce. Wheat has been an important part of our diet since it was first cultivated millennia ago.

Although many cases of coeliac disease are missed, there are also lots of people who think they have it and almost certainly don't. According to recent studies, around 13 per cent of the UK population are currently gluten-free, which is an impressive 13 times more than the number of people with coeliac disease.

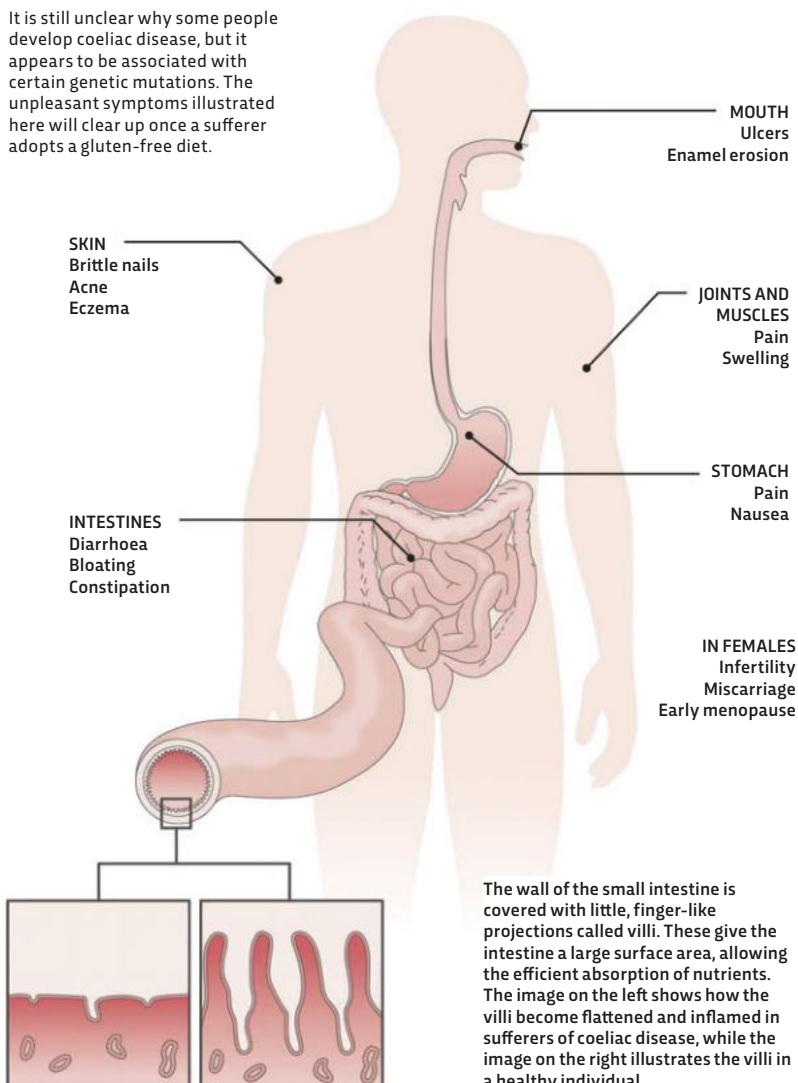
GOING AGAINST THE GRAIN

So are these individuals deluded or are they onto something? Well, it could be that some have a genuine wheat allergy. This is really rare, probably less than 0.1 per cent of the population, but it certainly happens. Again, the only way to find out is with a blood test.

Then there is a bigger group of people who may, or may not, have non-coeliac gluten sensitivity (NCGS). Symptoms include cramping, bloating and

WHAT IS COELIAC DISEASE?

It is still unclear why some people develop coeliac disease, but it appears to be associated with certain genetic mutations. The unpleasant symptoms illustrated here will clear up once a sufferer adopts a gluten-free diet.



diarrhoea. This is also very hard to diagnose, because there are no reliable tests. You arrive at the diagnosis by excluding everything else.

It's difficult to say just how common NCGS really is. In a recent Italian study, published in the journal *Digestion*, researchers examined 392 patients complaining of gluten-related problems.

They found that 26 out of the 392 (6.6 per cent) had undiagnosed coeliac disease and two (0.5 per cent) had a wheat allergy. The rest were put on a gluten-free diet and followed for two years. Those who were free of symptoms after six months were considered to have NCGS. In all, 27 people – just 7 per cent of the group – had NCGS. In other words, 86 per cent of this group of patients who thought they had some form of gluten-related problem really didn't. Or at least cutting out gluten from their diet made no difference.



"In other words, 86 per cent of the patients who thought they had a gluten- related problem really didn't"

The team concluded: "Self-perceived gluten-related symptoms are rarely indicative of the presence of NCGS".

If you have lots of gut symptoms and think you might be intolerant to gluten, then you should get yourself properly tested to exclude coeliac disease and wheat allergy. If the tests come back negative and you still

have a nagging feeling you might have NCGS or some other, as yet unnamed, gluten intolerance syndrome, then you might want to give a gluten-free diet a go.

It won't be easy because so many foods have gluten in them. You will also need to stick to a strict gluten-free diet for at least a month to see if your symptoms improve. Then, to make doubly sure, you should gradually reintroduce gluten and see what happens.

Foods that you will need to avoid on a gluten-free diet include anything with wheat, rye, barley or spelt. That means bread, pasta, cereals, cakes and biscuits are out. You will also need to lay off the beer and read labels carefully as many processed foods have gluten in them.

Frankly, skipping out many of these foodstuffs is likely to help you lose weight and make you feel better anyway. The main disadvantage of going gluten-free is that unless you are careful you may lose out on essential nutrients. ☺

FAR LEFT: Gluten-free foods are all the rage, but some could be packed with salt and sugar

LEFT: According to BBC's Michael Mosley (pictured), you could miss out on nutrients by avoiding gluten

BELLOW LEFT: Skin prick tests can help identify allergies to foods

BELLOW RIGHT: Genius is a brand of gluten-free bread that is available to buy in UK supermarkets, but can also be obtained on prescription by coeliacs





● You are not going to find many vital nutrients in cakes or biscuits, but breads and cereals are fortified with a range of vitamins and minerals. Unless you compensate by eating more fruit and vegetables, there is a risk of becoming deficient.

Avoid, like the plague, anything that markets itself as 'gluten-free'. It will almost certainly be junk. A sad thing about this scare is that worried parents are buying gluten-free children's food in the belief it's better, when it is often packed with unhealthy additions, like lots of salt.

MILKING IT

The other popular food 'allergy' to have is lactose intolerance. Lactose is a natural sugar found



Lactose

is found in milk and is derived from two sugars: galactose and glucose. In regions where milk forms a significant part of the adult diet, lactose intolerance is fairly rare. Most people of European descent can drink milk without any issues. Lactose is often added to foods and medications.

largely in milk and other dairy products. People who worry about lactose often do so on the grounds that drinking milk is 'unnatural'. They claim that we are the only species on Earth that consumes milk as adults, and this can't be a good thing.

Instead, we are encouraged to either avoid milk altogether or try one of the other variants, such as almond milk (vile) and soya milk (even worse). Sadly, the enthusiasm for almond milk has not even been slightly dented by studies suggesting that the water catastrophe playing out in California is partly down to the enormous growth in worldwide demand for almonds.

Unlike gluten intolerance, lactose intolerance is actually extremely common. When we're very

FREAKISH FADS

Some crazes are stranger than others, but they aren't all nonsense

ENEMAS

For those not familiar with an enema, it involves injecting a fluid into the lower bowel via the rectum. The main medical reason for carrying out an enema is to relieve constipation. Alternative practitioners, however, claim a wide range of other, unproven benefits.



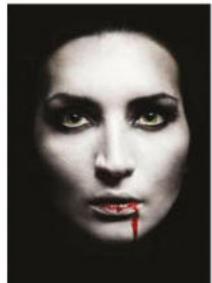
DETOXING/ FASTING

If you'd asked me a few years ago, I would have been sceptical about detoxing. But I've since looked into the research surrounding intermittent fasting and changed my mind. Restricting calories for two days a week can improve health.



VAMPIRE FACELIFTS

This consists of taking some of your blood, removing the red cells, then injecting the resulting platelet-rich plasma (prp) back into your face. It sounds flaky, but is based on good science and can accelerate healing.





"We are encouraged to either avoid milk altogether or try one of the other variants, such as almond milk and soya milk"

young we get lots of lactose in our diet, either from breast milk or from cow's milk.

Unlike most people in the world, those of European descent continue being able to enjoy milk and other dairy products when they are adults because their bodies produce a digestive enzyme called lactase, which breaks down lactose.

If, like 75 per cent of the world's population, you lose this enzyme as you grow older, then lactose will hang around in your digestive system, where it will be fermented by bacteria, leading to the production of lots of gas. If you are genuinely lactose intolerant then an hour or so after eating dairy products you are likely to experience flatulence (wind), diarrhoea, a bloated stomach,

ABOVE LEFT: If you're of European descent, you can probably enjoy a bowl of cereal without panicking about any after-effects

and start producing hydrogen. The downside of this test is that it can produce severe diarrhoea. Instead, you may prefer the stool acidity test, which is as straightforward as it sounds. You provide stool samples and if your stools are acidic, you are intolerant to lactose.

EAT UP

If you are neither lactose intolerant nor a vegan, then I think there is a considerable downside to avoiding dairy products. Cow's milk is incredibly nutritious (it has to feed a growing calf). It's rich in healthy proteins and fatty acids, but also calcium, vitamin D, vitamin B12, potassium and phosphorus, all of which are good for bones.

Those of you who have been persuaded (as I once was) that low-fat dairy is somehow 'healthier' should also bear in mind that low-fat versions are missing out on a wide range of healthy fatty acids and fat-soluble vitamins.

Individuals who are looking to follow a healthy diet will find that their wallets are considerably lighter after the weekly food shop if they fill their trolleys with free-from foods. So unless you have been diagnosed with a genuine intolerance or allergy, then a varied diet with lots of fruit and veg is still the best way to maintain optimum health. **F**

URINE DRINKING

I have seen people drink their own urine, gargle with it and even wash their hair in it. Unfortunately, I can find no scientific rationale for doing so. Perhaps if you had a sore throat it might be soothing?



Dr Michael Mosley is the presenter of *Trust Me, I'm A Doctor*, and author of *The 8-Week Blood Sugar Diet*, published by Short Books.



DRONE AWARE

www.droneaware.org



DO YOU FLY A DRONE?

- 1 There are legal requirements relating to the flight of all model aircraft, and also photography and filming with model aircraft - including multirotors.
- 2 Ensure that your proposed flying location is appropriate, safe and lawful. Do not fly in built up areas or close to people.
- 3 Do not endanger persons or property.
- 4 Maintain line of sight for the purposes of control at all times (see CAA Exemption for specific details of FPV flight permissions).
- 5 Ensure that you have appropriate liability insurance cover for the proposed activity.
- 6 Receiving payment for flights renders the activity Aerial Work, not model flying.
- 7 Do not cause a nuisance or invade privacy.

BE SAFE - BE LAWFUL - BE AWARE
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For further information on all aspects of model flying including the purchase of liability insurance (£25 million of cover provided for lawful model flying activity including multirotors and aircraft operated by FPV as standard with BMFA membership) contact the BMFA office.

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ROBIN INCE ON... LAUGHTER

"WHEN THE TRIBE LAUGHS AT YOU, THEY'RE REALLY TELLING YOU NEVER TO DO THAT AGAIN"

Which will come first: a universal theory that unites quantum mechanics and the General Theory of Relativity, or a scientifically scrupulous theory of humour, where laughter and the underpinning of all jokes is explained in a single, pithy sentence? My money remains on the universal theory.

"Why are they laughing?" is the question of the paranoid man and the lecturer in anthropology. Humour studies is accused of being humourless, but it's still fun to think about what makes something funny. Unlike biochemistry or cosmology, I don't think an objective and scientifically accurate theory of comedy is necessary, though jokes *can* help us to understand the structure of our brains, the nature of artificial intelligence and what it means to be human.

So why do we laugh? Maybe a good place to start is with a couple of things that make me laugh.

As a teenager, comedy was my obsession. I fell off my chair laughing at Rik Mayall stepping in dog poo in *More Bad News*. I've watched it over 50 times, and still it makes me laugh.

My other laughing-until-apoplectic highlight was Billy Connolly re-enacting the experience of bathing in the North Sea. His impression of the involuntary noise that comes out of your mouth as the cold sea touches your genitals was the funniest noise in the world to me.

Why would I experience near-death by joyful asphyxiation when seeing and hearing these things?

With Connolly's anguished cry, it may partly be the laughter of recognition. When we recognise ourselves in a comedian's routine, we're united with whoever else is watching or listening. Being a self-conscious being on a small planet can be a lonely, alienating business. This moment of laughter says, "You are not alone". That's why people can be so



furious when they don't get a joke; the noise of laughter is really an accusatory cry of "You are not one of us".

Rik Mayall's pratfall into poop may fall into the category of 'how laughter educates through shame'. It's an evolutionary thing. No one likes being laughed at, so when the tribe laughs at you, they're really telling you never to do that again. It's a way of controlling the behaviour of the group. The clumsy man on the mammoth hunt who slips on his own spear and ends up piercing his bottom is not very useful, so it makes more sense to laugh at him while he's still slipping in dung, before it's developed into the sort of behaviour that sees him impaling himself.

Laughter also offers solace during repression. When you're under the cosh, and physical rebellion is not an option, each joke you make at

the expense of the oppressor is a secret little victory. The philosopher Slavoj Žižek has recounted many of these; I don't have the space to recount a whole one, but my favourite ends with,

"But I got him! His balls are covered with dust!"

Then there's the theory that a punchline works by producing a twist in behaviour that delivers the unexpected, which makes me wonder how quantum physicists manage to get anything done when they must be perpetually blinded by tears of laughter.

I delight in pondering humour theories, but in the end, I realise that even when the most rigorous comedy research is complete, the punchlines in the pub won't be any better.

So maybe we should stop thinking about it and just enjoy the laughter. After all, in the words of Billy Connolly, "Good hearty laughter... it's just the most extraordinary thing you can do for a fellow human being." ☺

Robin Ince is a comedian and writer who presents, with Prof Brian Cox, the BBC Radio 4 series *The Infinite Monkey Cage*.

NEXT ISSUE: WHAT NEANDERTHALS DID FOR US

MAKING WAVES

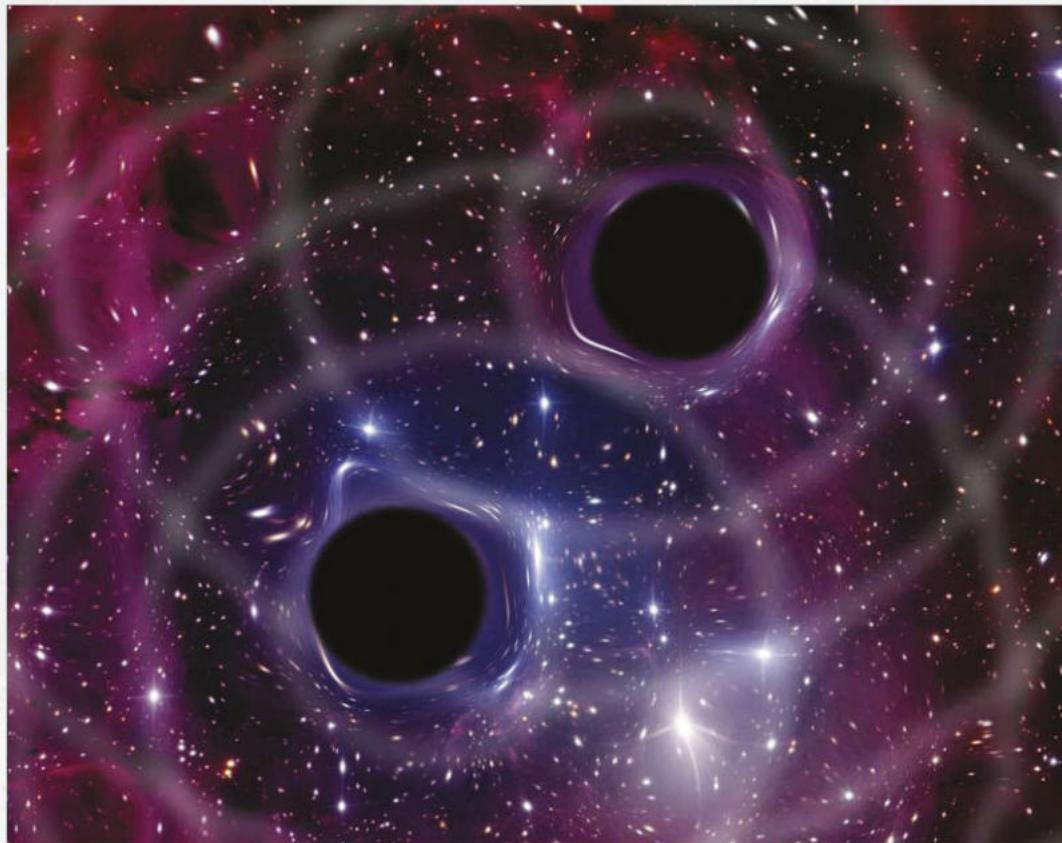


In February this year, physicists announced that they had detected gravitational waves towards the end of 2015. Could these ripples in the fabric of space-time help us decipher some of the strangest phenomena in the cosmos?

Words: Colin Stuart



In 14 September 2015, a new window into the Universe was opened. Researchers at LIGO (Laser Interferometer Gravitational-Wave Observatory) caught the distant murmurs of two black holes colliding, and in doing so made the first direct detection of gravitational waves. This discovery is yet another victory for Einstein's General Relativity. But more than that, because gravitational waves carry information about some of the most exotic events in the cosmos, they will allow astronomers to see the Universe in a new way. At the beginning of this revolution, here are some of the game-changing developments astronomers may uncover in the years ahead.



ABOVE: When two black holes merge, they alter the motion of gravitational waves

Black holes

The signal picked up by LIGO is believed to have come from two huge black holes colliding 1.3 billion light-years away. One of the black holes in the merger detected by LIGO was around 29 solar masses (one solar mass = the mass of the Sun), the other tipped the scale at 36 solar masses.

By analysing the way the gravitational waves changed as the black holes spiralled towards each other, the LIGO team established that the two black holes were initially orbiting each other 30 times a second, but this ramped up to 250 times, before a telltale ‘chirp’ in the signal indicated that the two behemoths had combined.

LIGO and other gravitational wave experiments will help us learn more about black holes and General Relativity.

“One of the most dramatic predictions of General Relativity is that black holes with large spins will dance in their orbits,” says Prof Bangalore Sathyaprakash from Cardiff University. “It is impossible to mimic such an experiment in any laboratory or with other astronomical observations. They will only be visible in the gravitational window and that’s something we hope to observe in the coming years,” he adds.

WHAT ARE GRAVITATIONAL WAVES?

Gravitational waves are ripples in the fabric of space-time. Think of space a stretched sheet of nylon. If you placed a bowling ball into the centre, the fabric would warp and sink, creating a kind of funnel. Drop any more balls onto the sheet, and they’ll

roll towards the centre where the bowling ball is. The Sun makes a similar depression in space itself, giving rise to the gravity that pulls Earth towards it.

As an object accelerates through space – say a planet orbiting a star – its motion

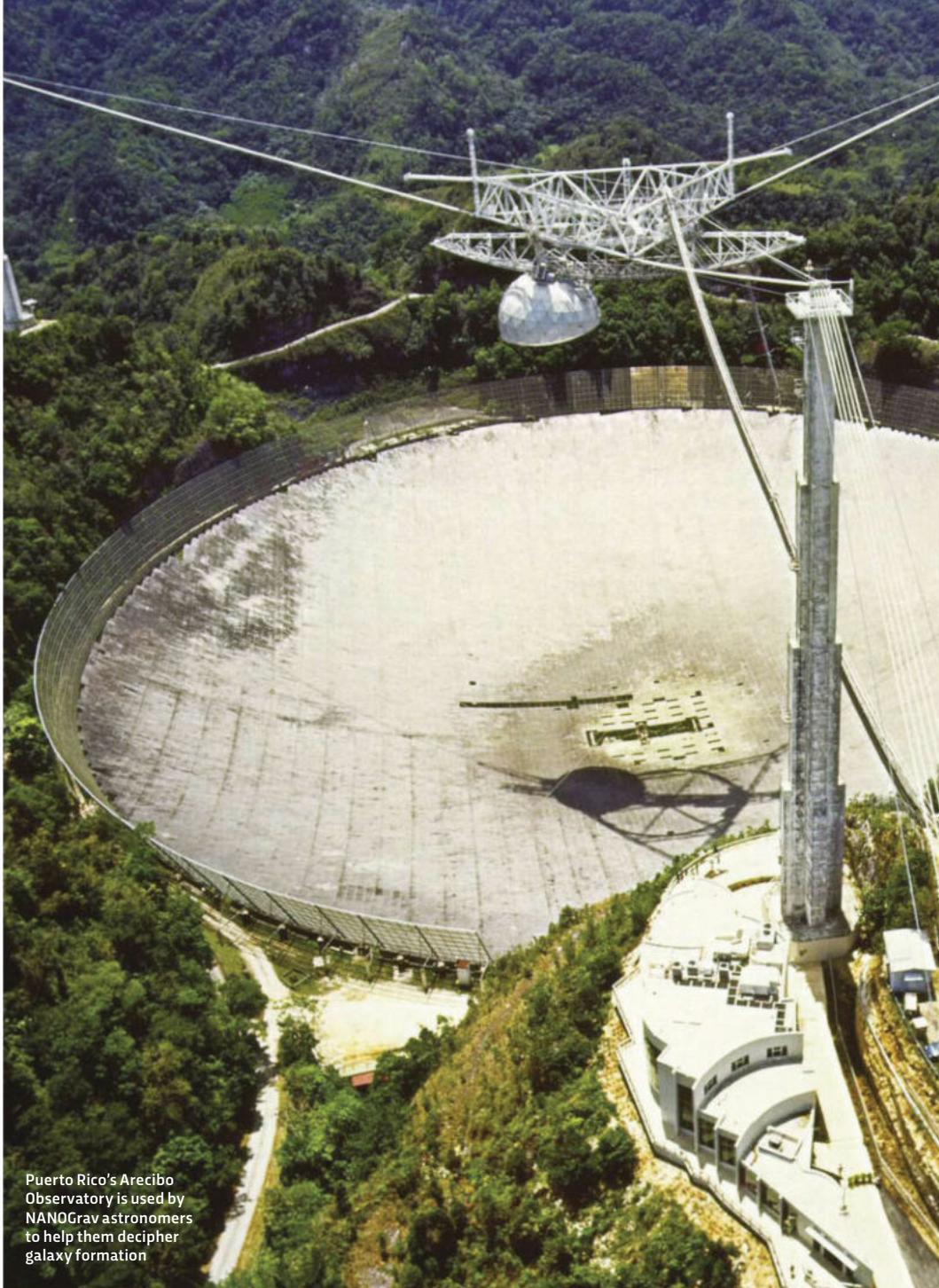
causes distortions in this fabric, which ripple outwards as waves. The bigger the mass of an object, the bigger the waves. The recently spotted gravitational waves came from two colliding black holes – some of the hugest objects in the Universe.

Galaxy formation

The black holes observed by LIGO are tiny compared to those found at the centre of some of the most massive and distant galaxies. Take the system known as OJ 287, for example. Here, a hefty black hole of 100 million solar masses encircles a beast of 18 billion solar masses.

Such humongous beasts are thought to have been formed by a succession of previous mergers. Given that most galaxies are thought to host such supermassive black holes at their centre, systems such as OJ 287 could give us clues about the role that black hole mergers play in galaxy formation.

Gravitational waves emitted by a system like OJ 287 are too low frequency to be picked up by LIGO. Instead, astronomers are hoping to detect the waves indirectly by observing their effect on pulsars. This is the kind of measurement that the North American Nanohertz Observatory for Gravitational Waves (NANOGrav) will be detecting.



Puerto Rico's Arecibo Observatory is used by NANOGrav astronomers to help them decipher galaxy formation

A tiny neutron star alongside a larger white dwarf

Neutron stars

Neutron stars are compact, city-sized stellar objects resulting from the explosive death of much larger stars. They are incredibly dense – a neutron star the size of a golf ball would weigh around one billion tonnes. They spin extremely rapidly thanks to the power of the explosion from which they are created.

It is thought that some rapidly rotating neutron stars have

'mountains' on their surface. These asymmetries should generate gravitational waves as the neutron star spins. Detecting such waves would be a real boon for theorists trying to understand how these mountains form.

"Unfortunately, the processes leading to these deformations are very difficult to model. A direct observation would give us important insights into the star's history," says the University of Southampton's Prof Nils Andersson.

Studying gravitational waves may also help astronomers to pin down the exact size of these extreme objects, Andersson says.

Dark energy



In the 1990s, astronomers found that the expansion of the Universe is speeding up. This was unexpected because it was thought that the expansion would be slowing down as the initial force of the Big Bang continued to fizzle out.

It is thought that an invisible material, known as dark energy, is acting as a sort of anti-gravity and pushing clusters of galaxies apart.

Measuring distance in space has traditionally been done using events such as Type Ia supernovas. These explosions have an initial fixed brightness that fades over distance and are known as 'standard candles'. Gravitational waves could offer an alternative approach. Waves from colliding black holes get smaller as they spread out through space. These fading chirps would provide a new measuring stick called a 'standard siren'.

"This can be compared with dark energy models for the expansion history of the Universe, and so measure dark energy, hopefully better than the Type Ia supernovas," says Prof Andy Taylor at the Royal Observatory, Edinburgh.

"Gamma-ray bursts (GRB) are among the most violent and energetic events seen in the Universe"



We still don't know for sure what causes gamma-ray bursts

Gamma-ray bursts

Gamma-ray bursts (GRB) are intense explosions of gamma rays and are among the most violent and energetic events seen in the Universe.

Currently, we can only observe these events if the beams of gamma rays conveniently head in our direction. But the gravitational waves created by GRBs travel out in all directions.

Observing gravitational waves could also help us to work out what is causing so-called short GRBs – those that last less than two seconds. The current leading contender for the origin of short GRBs is the collision of two neutron stars, but astronomers have so far been unable to detect the proverbial

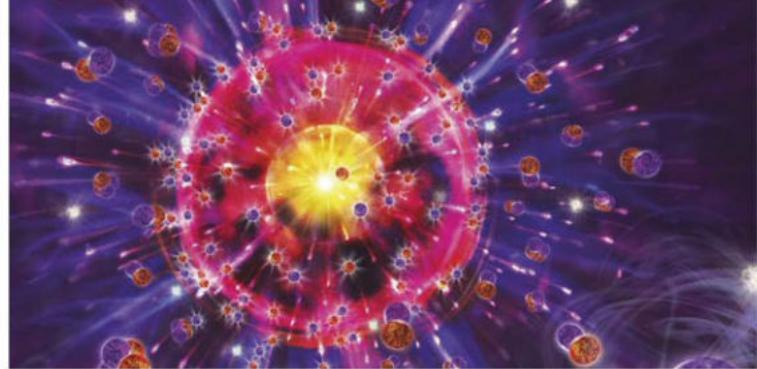
smoking gun. However, this could be about to change. Within the next two years, upgrades to the LIGO experiment will make the detector sensitive enough to pick up any neutron star mergers occurring in the closest 300,000 galaxies.

"Seeing both a gamma-ray burst and gravitational wave would completely nail down the progenitors of GRBs, because with a gravitational wave signal we directly measure the mass of the merging system," explains Prof Andrew Levan from the University of Warwick. "Studying the gravitational waves means we can see these mergers even when the gamma rays are directed away from us."

Cosmic inflation

When astronomers try to peer into the early Universe, they hit a smoke screen around 380,000 years after the Big Bang. At this time the Universe was composed of a dense sea of subatomic particles that prevented light from escaping, which means there's nothing to detect to tell us about the early Universe. Gravitational waves, however, would have been able to spread unhindered, allowing us to look back further than previously possible.

Observations of gravitational waves could be used to test a theory known as inflation. It's the idea that the Universe underwent a rapid burst of expansion in its earliest moments, taking it from



When the Universe first expanded, it could have sent gravitational waves rippling through space-time

many times smaller than an atom to about the size of a marble in a trillionth of a trillionth of a trillionth of a second. This extreme growth spurt could have sent gravitational waves rippling through the fabric of space-time.

LIGO doesn't operate at the right sensitivity to pick up the kind of gravitational waves thought to have been spawned by inflation, but the next generation of detectors might find them.

"Their amplitude would point to the energy scale of inflation, which is a major unknown," says Prof Uros Seljak from the University of California at Berkeley.

"The feather and the hammer hit the lunar dust at exactly the same time, despite their vastly different shapes and masses"

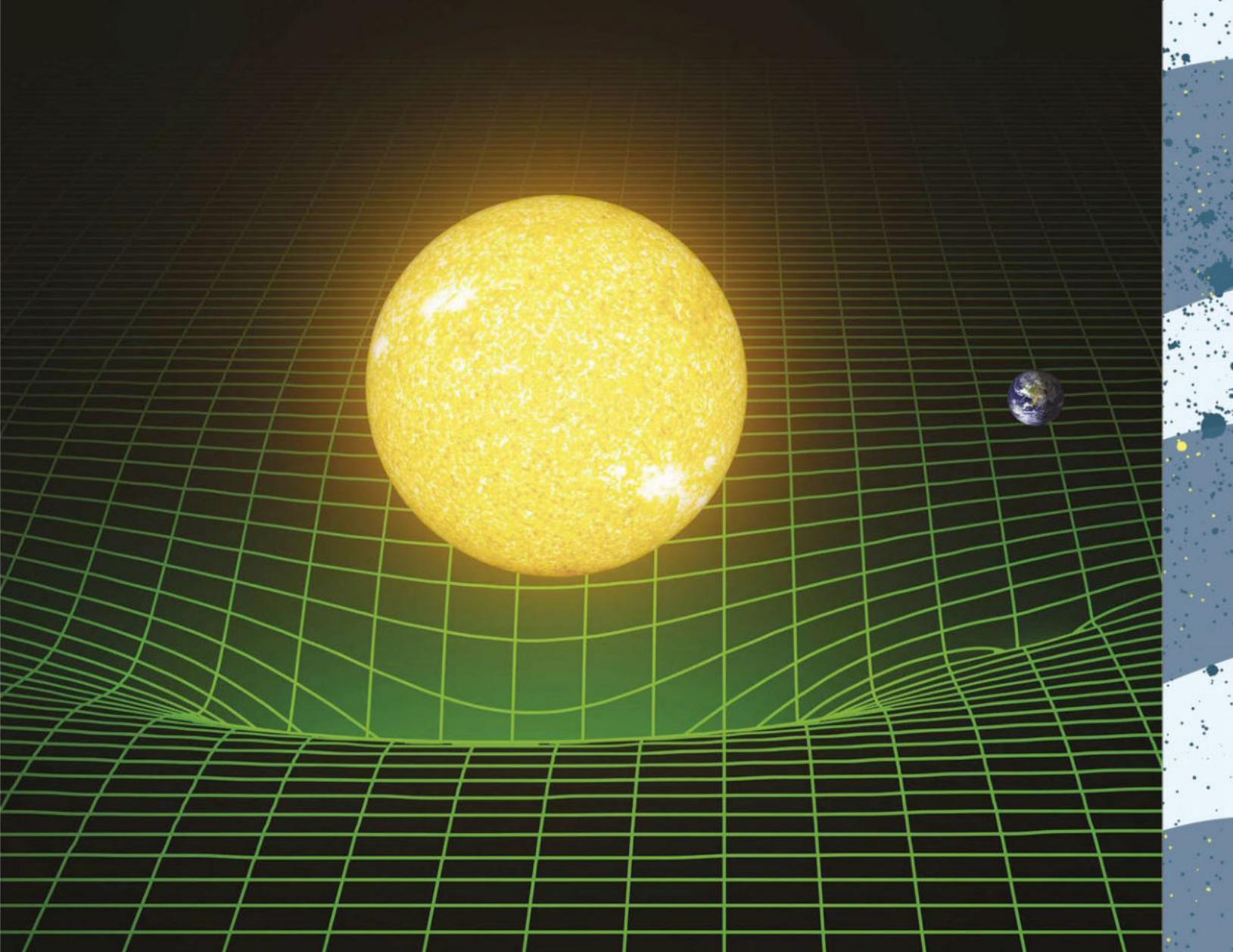
Equivalence principle

LIGO's detection of gravitational waves ended a game of cosmic hide and seek that began 100 years ago when they were predicted by Einstein's General Theory of Relativity. Now that we have found them, gravitational waves could be used to test another cornerstone of Einstein's theory: the equivalence principle. Put simply, it says that all objects, irrespective of their composition, fall with the same acceleration in a gravity field. The most famous example is the feather and hammer dropped on the Moon by Apollo 15's Commander Dave Scott in 1971. Both objects hit the lunar dust at exactly the same time, despite their vastly different shapes and masses.

But just because the equivalence principle holds in our Solar System, it doesn't necessarily mean it is universal. That's where gravitational waves come in. A recent paper published by Xue-Feng Wu of the Purple Mountain Observatory in China calculated that combining light signals with gravitational waves from the same event could help test the equivalence principle to an accuracy of 0.000000001 per cent – several factors of 10 better than the best current efforts.



Hammer time: a feather and hammer dropped on the Moon hit the lunar surface at the same time, proving Einstein's equivalence principle



Einstein's General Relativity says that space-time is warped by massive objects, but this doesn't work with quantum physics

Gravitons

Perhaps the ultimate quest for physicists is to find a single, coherent theory that can explain all phenomena in the Universe. We currently have Einstein's General Relativity to explain the very big, and quantum physics to explain the very small, but the two are at odds with one another.

Part of the problem is that gravity, as explained by General Relativity, doesn't seem to want to play nicely with the other three fundamental forces of nature: the electromagnetic force, the strong nuclear force and the weak nuclear force. These three forces are known to be mediated by gauge bosons – particles known to transmit force. It is thought that there is an equivalent for gravity called 'gravitons', but we haven't found them yet.

In conventional General Relativity, gravitons are predicted to be massless. However, in their efforts to piece together a theory that combines General Relativity with quantum physics,

theorists have been toying with the idea that the graviton may in fact have mass. "If the graviton had a mass it would change the black hole chirp. As this is very accurately measured it puts very strong constraints on it," says Prof Andy Taylor from the Royal Observatory, Edinburgh. This means that by studying the behaviour of gravitational waves, researchers will be able to investigate the possibility that the graviton has mass, taking them a step closer to the elusive theory of everything. 

Colin Stuart (@skyponderer) is a freelance astronomy writer and author. His most recent book is *Physics In 100 Numbers*.

DISCOVER MORE

 Find out more about LIGO and gravitational waves at ligo.caltech.edu

 Listen to the sound of two black holes merging at bit.ly/merging_black_hole

SURVIVAL OF



THE FITTEST



PHOTO: COURTESY OF MONOLITHIC

Thirty years on from the Chernobyl nuclear disaster, the area is still not safe for human inhabitants. Will we ever be able to move back in? We look at how humans are adapting to life in some of the most hazardous and inhospitable places on Earth

WORDS: CATHERINE OFFORD

DISASTER-PROOF HOMES

LOCATION: Philippines

In 2013, Typhoon Haiyan crashed into the Philippines, killing more than 6,000 people and causing 89.6 billion pesos (£1.3bn) worth of damage. Now, US company Monolithic is helping to construct specially-designed dome houses that have a better chance of surviving future storms in the Philippines and elsewhere.

With a curved surface, the domes are able to withstand high winds (not to mention earthquakes) much better than flat roofs and walls can, as the self-supporting shape helps to distribute stress around the structure. Add to this an extremely strong reinforcing material made from basalt, and you have a virtually disaster-proof home.

In 2015, Monolithic launched a project to build 50 domes to house 200 families in Dapitan, a coastal town on the Philippine island of Mindanao, but construction work has been set back by in-country delays. Meanwhile, the company also supports similar, smaller-scale projects worldwide, from Indonesia to Haiti.



EROSION-PROOF FARMS

LOCATION: Australia

Bushfires burned thousands of hectares of land in South Australia at the end of 2015, destroying vegetation and leaving the remaining soil susceptible to wind erosion. But Brian Fischer, a sheep farmer near Adelaide, took to his tractor to stop the situation getting worse.

Over 10 days, he and his two sons put into action a method Brian's father had used after droughts back in the 1940s: ploughing the land

in spirals. "The theory is that whichever way the wind blows, it can't get a start to erode the soil because it's always blowing against the trenches," explains Fischer.

Now a ridged mat of geometric patterns, the farmland's 400 hectares help prevent dust storms from forming, protecting the precious few inches of topsoil that cover the infertile clay or limestone rock beneath.



DESERT STOPPER

LOCATION: China

PHOTO: GETTY, IMAGINE CHINA



The Three-North Shelterbelt Program, aka the 'Green Great Wall', was launched in 1978 to halt the creeping advance of the Gobi Desert into northern China. Not to be confused with the Great Green Wall, a similar initiative planned for the Sahara, the project aims to plant a belt of trees that will block the path of wind and dust storms from the north and strengthen the soil with their roots, helping to prevent desertification.

At nearly 4,500km (2,800 miles) long, the belt should consist of roughly 100 billion trees by its scheduled completion date in 2050. But although 66 billion trees have already been planted, the project has faced – and continues to face – many challenges, including the loss of a billion poplar trees to disease in 2000, and continuing desertification caused by over-farming and poor use of land.

FOG COLLECTORS

LOCATION: Worldwide

Even in the driest parts of the world, fog offers a source of clean water – provided it can be collected. Using a cheap commercial mesh designed for shading plants, scientists at FogQuest have created 'fog collectors' that can trap an average of five litres of water per square metre of mesh per day – or up to 30 litres in particularly wet and windy conditions.

"Fog droplets are really tiny, from one to 25 microns in diameter," says Robert Schemenauer, an atmospheric scientist and co-founder of FogQuest. "The wind pushes them against the mesh, and then gravity pulls the big droplets down, moving the water through connected pipes to a cistern."

Since 2000, FogQuest has helped to set up fog collection projects in arid environments all over the world, from the Atacama Desert in Chile to the Everest region in Nepal.



RUBBISH ISLAND

LOCATION: Belize

Westpoint Island is one of several sandy islets in the shallow Caribbean waters around the island of Tobacco Caye, Belize. But unlike its neighbours, Westpoint is man-made – or at least its foundations are, having been constructed mostly from junk.

An 8,000m² speck on the map, Westpoint is the project of local fisherman Gerald McDougall, who began constructing the island back in 2006 after noticing how sand built up on rubbish thrown away by hotel resort workers.

The island's base is made from layers of sorted rubbish, including plastic bags and burnt cans, interspersed with layers of mud, sand and sawdust that help to retain water and promote plant growth. Despite being battered by bad weather in recent years, the little island is still standing, and McDougall uses it as a base from which to sell his fish to local markets.



MAN-MADE GLACIERS

LOCATION: Himalayas

Water is in short supply in the Himalayan desert during spring – a problem that the Ice Stupa Project, launched in 2014, aims to solve by growing glaciers from scratch.

The technology is surprisingly simple. "You put one end of a pipe upstream and take the other end of the pipe where you want water," explains engineer and project founder Sonam Wangchuk. "Since water always maintains its level, if you have one end upstream, higher in altitude, then the water downstream will jet out in a fountain. In the cold air on the Tibetan plateau, this water freezes as it falls."

Over time, ice builds up from the ground, creating conical towers that Wangchuk calls 'stupas' because of their resemblance to the Buddhist structures of the same name. Unlike real glaciers higher up in the mountains, which remain frozen until the summer, ice stupas melt in the spring, when the farmers need water for their crops.

The largest stupa stands 20m tall, holding around two million litres of water, but the majority of the dozen stupas currently being built are smaller mounds grown in stream beds to provide water for village communities.



REPAINTING MOUNTAINS

LOCATION: The Andes

Light-coloured surfaces reflect heat better than dark ones do. This was the simple premise that inspired inventor Eduardo Gold to tackle glacial melting in the Andes in the mid-2000s.

In the hope of cooling the ground enough to encourage new glaciers to form, Gold and a few helpers began the Herculean task of painting a mountain white.

The team used eco-friendly paint made from lime, egg whites and water, and received international attention when the initiative was named one of the World Bank's '100 ideas to save the planet' in 2009. But the project suffered managerial setbacks and funding shortages, and Gold's death in 2014 effectively brought work to a standstill.

A handful of other ideas have been tested since, including using liquid nitrogen to keep glaciers cool, but scientists are increasingly advising a different approach.

"Glaciers are retreating very fast," says glaciologist César Portocarrero of the Peruvian Institute for Glaciology and High Mountain Ecosystems. "But it's impossible to stop them retreating. It's a global problem. What we have to do is work against the effects of glacial retreat." **F**



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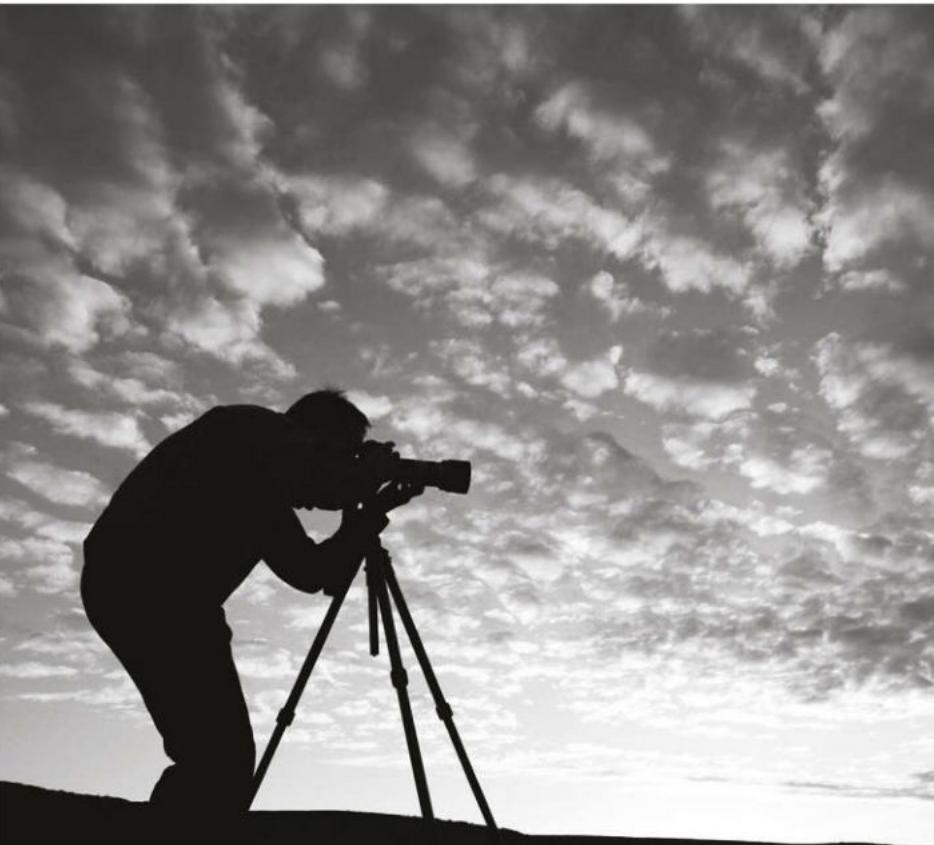
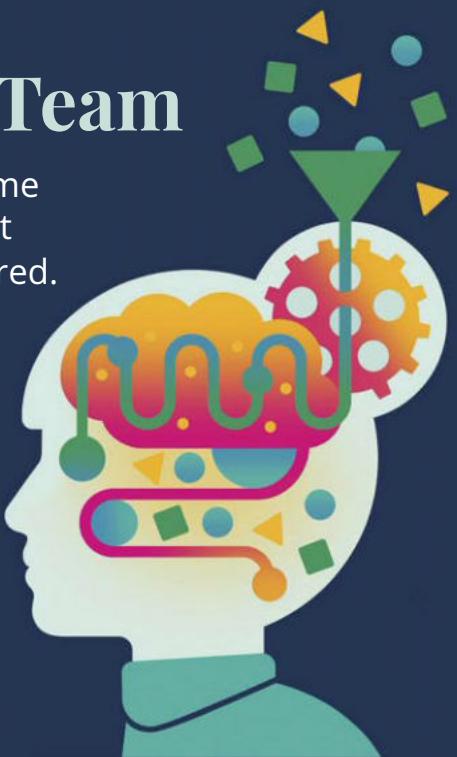
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ROBERT MATTHEWS ON... **WHY BMI IS BS**

"WORLD-CLASS RUGBY PLAYERS AND BOXERS OFTEN END UP CATEGORISED AS WADDLING FATTIES"

F

irst thing every morning I go through the same ritual. I stand on the bathroom

scales to check if my weight is below 11st 7lb. If it's not, my day is pretty much ruined. But if it is, I feel happy for, oh, as long as 30 seconds. The reason: 11st 7lb is the weight above which someone of my height becomes an official, certified lard-arse. Health experts put it slightly more politely: it's the weight that, when expressed in kilograms and divided by the square of my height in metres, gives a Body Mass Index (BMI) in excess of 25 – which classifies as overweight. And that, in turn, means I'd face a greater risk of ill health and an early death.

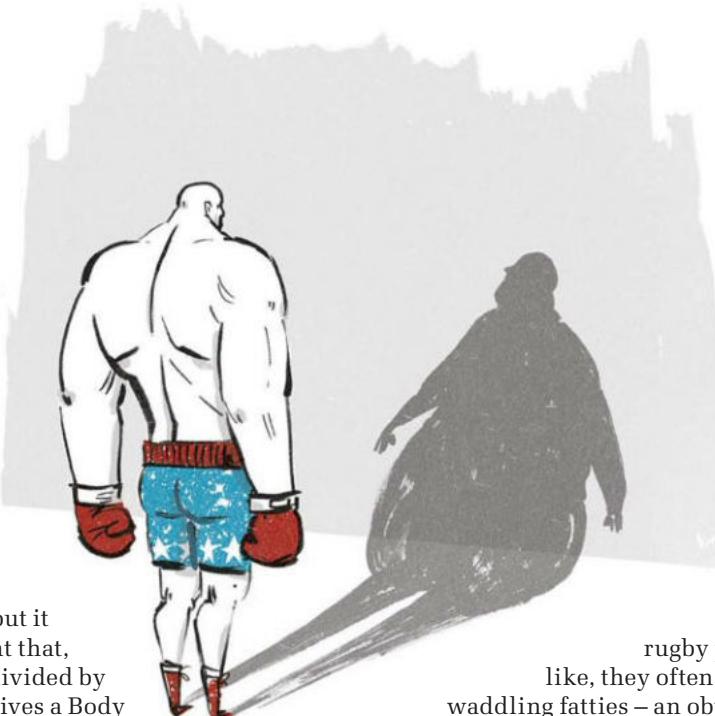
Is it any wonder, then, that I feel depressed when the digital display of the scales flashes up '11' followed by an '8' (or, if it's Sunday morning, '12')?

Yes it is, because I feel happy or depressed despite having known for years that the whole ritual is nonsense. The BMI is, bluntly, pure bull.

The idea of a simple formula that separates the lean-and-healthy from the fat-and-doomed is undoubtedly alluring. It has its origins in research carried out more than 150 years ago by Adolphe Quetelet, a Belgian statistician obsessed with the idea that human traits follow mathematical laws. After studying data on human development, he argued that human weights are typically proportional to the square of height. Quetelet didn't have decent scientific explanation for this; his 'law' just fitted the data.

That didn't matter too much until the early 1970s, when the influential American public health researcher Ancel Keys made Quetelet's formula the basis of research into obesity. Keys coined the term Body Mass Index, and it's remained central to research into obesity ever since.

Yet it's always been clear that the BMI can be very misleading. Sure, people who are unhealthily fat tend



to have large BMIs – but you can't simply flip that around and insist that having a large BMI means you're unhealthily fat. That's like arguing that because everyone with Ebola starts with a fever, everyone with a fever has Ebola.

This isn't just logical nitpicking. If you calculate the BMIs of world-class rugby players, boxers and the like, they often end up categorised as waddling fatties – an obvious absurdity. That's because muscle is denser than fat, so if you're healthy but powerfully built, you'll end up with the BMI implying you're overweight.

You don't have to be professional boxer Wladimir Klitschko, whose fighting weight BMI makes him a 'flabby' 28.4 (you can tell him), to fall foul of the formula. There is a heap of evidence that shows BMI fails miserably for the rest of us too.

The latest comes from researchers at the University of California, who compared the calculated BMIs of over 40,000 people with actual measurements of health markers like blood pressure.

The research study showed that nearly half of those who were classified as overweight had perfectly good health marker levels. And the flipside was also true: more than 30 per cent of those with BMI values in the 'healthy' range proved to have dodgy health markers.

I'd bet I fall into this latter category. Yet somehow I can't stop putting my trust in Keys' simple yet patently silly formula. The trouble is, neither can health policymakers – and until they do, many of us will remain self-deluded fatties.

Robert Matthews is visiting professor in science at Aston University, Birmingham. His latest book *Chancing It: The Laws Of Chance And What They Mean For You* is out now (Profile, £14.99).

DISCOVER MORE

Listen to *Slimboy Fat: The Problem With BMI* at bit.ly/Slimboy_Fat

NEXT ISSUE: WHY WE SHOULD QUESTION THE EXPERTS

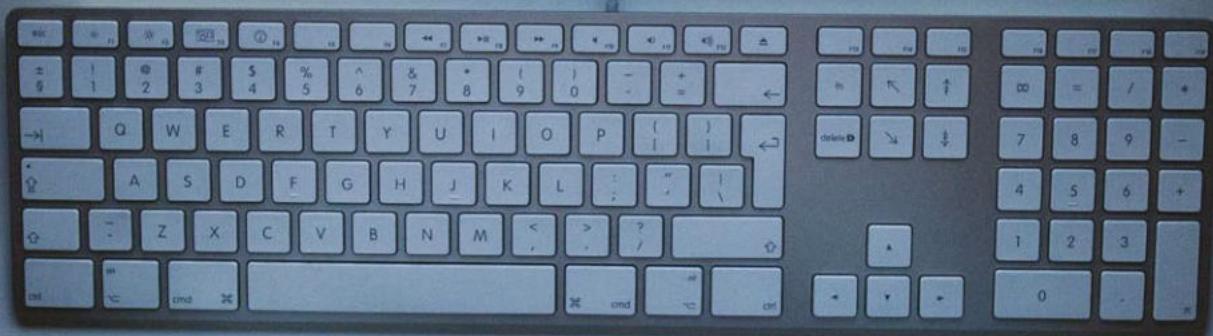
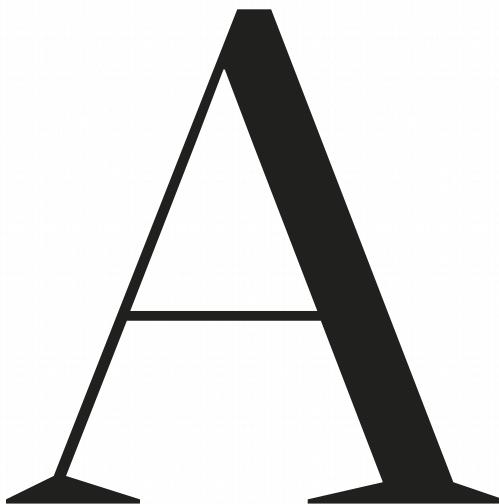


PHOTO: GETTY

IS PORNOGRAPHY WARPING OUR BRAINS?

IN A HIGHLY CONNECTED AND MOBILE WORLD, IT'S EASY TO GET HOLD OF PORN. BUT IS IT A HARMLESS WAY TO SPICE UP YOUR LOVE LIFE, OR SOMETHING MORE SINISTER?

WORDS: ZOE CORMIER



s anyone who has been on the wrong end of an unfortunately worded Google search can attest, pornography is easier to access than ever. Thanks to the proliferation of the internet, explicit videos and images are now no more than a few key taps away – it's simply a fact of modern life. It's little surprise then, that studies show most of us have seen pornography of some form at least once. There are some of us, however, that can't seem to get enough and watch upwards of several hours a week. What effect is this having on those people? Is it all just a bit of harmless titillation, or is there a more sinister side to watching pornography? The research seems to suggest there is.

An experiment by Valerie Voon of the Department of Psychiatry at the University of Cambridge found that people with 'compulsive sexual behaviour' show different patterns of brain activity when viewing erotic images compared to 'healthy' controls. These are similar patterns to those seen in drug abuse. So could pornography actually be harming us?

Voon and her team used magnetic resonance imaging (MRI) to probe deep into the anatomy of the brain. They found that there was greater activity in three distinct regions of the brain in people who exhibit compulsive sexual behaviour. These are implicated as being more active in people with substance problems when shown 'cues' linked to their drug of choice. The ventral striatum is involved in handling reward and motivation, the dorsal anterior cingulate with anticipating rewards and craving, and the amygdala with processing emotions.

There has long been concern about the potential damage of

consuming porn. For years headlines have screamed: "Porn addiction messed up my life", "Brain scans find porn addiction" or "My husband's porn addiction almost ruined our marriage".

And Voon's research is not the first to find differences in the brains of people with above average porn habits. Many studies have hinted at measurable differences in the brains of people who watch a lot of pornography, suggesting addictive and possibly harmful impacts.

A 2014 paper in the journal *JAMA Psychiatry* titled 'Brain Structure And Functional Connectivity Associated With Pornography Consumption: The Brain On Porn' found decreases in activity in many areas of the brains of regular porn viewers. The researchers even suggested porn can hijack the brain and alter its function. However, they did note that these differences could be pre-existing characteristics in the brain that predispose some people to find viewing pornography more rewarding than the average person.

Nevertheless, the results raise some big questions. Does porn change your brain? And is it addictive?

BRAIN DRAIN

Without a doubt, the most active and controversial area of research on pornography today is whether or not porn can be addictive. News reports routinely use the language of addiction, describing 'cravings', 'tolerance', 'need for more hits' and 'withdrawal'. "We are still in the very early stages of understanding these processes on a neurobiological level," Voon says. "What we do know with porn is that there are some patterns that are consistent with an addiction – but some that are not. We need much larger epidemiological studies to know for sure."

As yet there are no officially recognised diagnostic criteria for 'porn addiction'. Attempts to include 'hypersexuality disorder' in the *Diagnostic And Statistical Manual Of Mental Disorders, Fifth Edition* (DSM-5) – the so-called 'bible of psychiatry' – were unsuccessful due to a lack of clear and consistent evidence. ☀

"There are some patterns that are consistent with an addiction – but some that are not"

Women Against
Pornography marching
in New York in 1979



"For some, excessive and compulsive use has led to difficulties in relationships, lost jobs due to watching porn at work and even suicide attempts"

addictions, such as gambling and drugs, in that they activate reward circuitry. But they do not look like them in other important ways. For one, people with problematic porn use report they have a lack of control – but when tested for it, that appears not to be the case, she says. But the main difference is that with addiction to drugs and gambling, addicts experience ‘sensitisation’: they become more sensitive to the cues of their addiction, and her research indicates porn decreases sensitivity.

Meanwhile, Voon says there is good evidence that excessive consumption of porn can lead to ‘habituation’: the desire for novel stimuli. This means regular viewers crave more hardcore scenes the more they watch. This is a trend that many men have reported anecdotally and sought treatment for.

“Although I wouldn’t yet call it an addiction, it certainly is a compulsive sexual behaviour, and there is no question that for some people excessive and compulsive use has led to difficulties in relationships, lost jobs due to watching porn at work and even suicide attempts,” Voon says. Last year she and her team published a study suggesting that online porn in particular can allow sex addicts to chase after more novel and hardcore images, onwards and onwards down the rabbit hole of the internet, enabling and worsening their addiction. “For some people this did escalate into watching more hardcore forms.”

There is agreement, however, that much more work needs to be done. “We don’t know a lot about these disorders, but there is no question that a lot of people are suffering,” says Voon. “There is a lot of shame, so a lot of people don’t seek help. The more we can recognise this as a disorder, the more we can decrease the shame surrounding this, and increase both the

likelihood of people coming for treatment and our chances of helping them.”

● “Pornography ‘addiction’ does not look like other addictions – full stop,” says Nicola Pausse, a neuroscientist formerly at UCLA but now founder of sexual health start-up Liberos LLC. According to Pausse, so-called porn and sex ‘addictions’ look similar to other

likelihood of people coming for treatment and our chances of helping them.”

VIOLENCE AGAINST WOMEN?

Modern studies of ‘the brain on porn’ are undoubtedly headline-grabbing and provocative. But this is not the first time that scientists have scrutinised pornography and the ways it could impact the human condition.

In the 1970s, there was widespread concern that porn was contributing to sexist attitudes, ultimately leading to a rise in violent assaults. The fears were understandable. But have scientific studies been able to turn up any evidence?

“The academic aim was to take radical feminist ideas and put them into testable hypotheses,” says psychologist Prof Neil Malamuth of the University of California Los Angeles. “I wanted to find the characteristics of men who were more likely to be aggressive towards women – porn was just one factor among many.”

Decades of research, he says, have shown that for men, excessive viewing of pornography is consistently associated with sexist attitudes, coercive acts, aggressive behaviour and other dangerous outcomes. A meta-analysis – a study of studies – published by Malamuth in 2009 found that hundreds of papers from the 1980s to 2008 were fairly consistent in linking high rates of porn viewing with violent ideas and behaviour.

But here’s the caveat: not all men respond to porn in the same way. For most men, consuming porn will not cause them to view women differently. But in those who already are predisposed to hold sexist views or to behave in an aggressive fashion, porn can exacerbate pre-existing and dangerous propensities.

In this way, it’s just like any other drug. Alcohol, for example, is in many ways comparable to porn because it is ubiquitous, socially acceptable and legal.

“For some people, alcohol can truly ruin their lives,” explains Malamuth. “But for others it can be mildly positive, such as providing stress relief or enhancing their sex lives. It depends on the cultural context – and the individual.”

But can watching porn actually be beneficial to certain people? Pausse thinks so. “There is as much of a case to be made for the benefits as well as the harms,” she says. For example, porn can introduce viewers to new activities that can ‘spice things up’ in the bedroom. “There is good evidence for mimicry, so we have good evidence that sometimes viewing ●

In 2014, certain acts were restricted in British-made porn films, leading to highly publicised protests in London



➲ porn can increase people's tendency to perform oral sex. Erotica can have positive and negative effects, it's about identifying for whom, and when."

The field is riddled with misconceptions and biases that are not supported by the data, she says. Despite concerns that porn can decrease libido and lead to impotence due to 'tolerance' and 'desensitisation', research published by Prause in the journal *Sexual Medicine* in 2015 shows these worries to be unfounded.

Similarly, it is accepted as gospel truth that rates of pornography viewing have increased dramatically with the rise of the internet, allowing for instant access to a huge diversity of images at home. But in fact, Prause says, statistics indicate that the number of people viewing pornography overall hasn't changed since the introduction of the video recorder. Even more surprisingly, more recent research has gone against studies from the 1980s and 1990s: increased access to pornography can often lead to *decreases* in rates of sexual assault. These findings emerged after changes to the laws in parts of Canada, Croatia, Denmark, Germany, Finland, Hong Kong, Shanghai, Sweden and the US allowed easier access to imagery.

Although Prause disagrees with the conclusions of other researchers such as Malamuth, she does agree – along with just about every other sex researcher – that porn can be extremely dangerous for some men because it can reinforce pre-existing beliefs.

"The most well-replicated and concerning harm is reinforcing rape myths in men who already believe them," says Prause. Such that if you take a woman on a date, she owes you sex. Or that women secretly want to be coerced into sex.

"People who already hold these ideas and who start to watch violent erotica will start to believe those myths more strongly over time, and that is definitely associated with sexual assault," says Prause.

Moreover, not just any type of porn will contribute to this problem. Run-of-the-mill vanilla porn does not tend to reinforce dangerous attitudes, she says, but violent porn certainly can.

On the plus side, Prause says that researchers could potentially use porn in a lab setting to treat those with

"People who already hold these ideas and who start to watch violent erotica will start to believe those myths more strongly over time. That is definitely associated with sexual assault"

violent, abusive inclinations. "If we can reinforce that these films are fantasy, not reality, it is possible to actually reduce the harms from erotica," she says.

PORN PROPAGANDA

A big problem with researching porn, says psychologist Dr Taylor Kohut of the University of Western Ontario, is the way that it is portrayed in the media.

"Magazines like to sell a tighter, neater story than actually exists, and this can be a huge problem because researchers often get their ideas about what should be studied by what they see in the news. There is a relationship between the two, and it is reciprocal and symbiotic," he says. "It's not always negative, but it is significant."

Kohut meticulously documented 'asserted harms' in media reports on porn, ranging from sexual assault and rape myths to communism and organised crime, in a 2015 paper frankly titled 'How The Popular Media Rushes To Judgment About Pornography And Relationships While Research Lags Behind'. He found the five main ideas on porn you see in the media: are porn is addictive, porn is good for relationships, using porn constitutes adultery, using porn makes your partner feel inadequate, and porn changes your expectations about sexual behaviour. This represents a wider spread of opinions than current research perhaps reflects.

"My biggest concern regarding the scientific study of porn is that a noticeable subset of researchers come at these issues with a focus on harm in their minds. They try to establish ways to confirm that porn is causing whatever harm they already believe exists," he says. "The field needs more people who are willing to look at the data and leave aside their politics and their issues." 

Zoe Cormier is a freelance science journalist and author of *Sex, Drugs And Rock 'N' Roll: The Science Of Hedonism*.

DISCOVER MORE

 Listen to a BBC Radio 4 episode of *Analysis* that discusses what we really know about pornography, including an interview with Prof Neil Malamuth, at bit.ly/porn_analysis

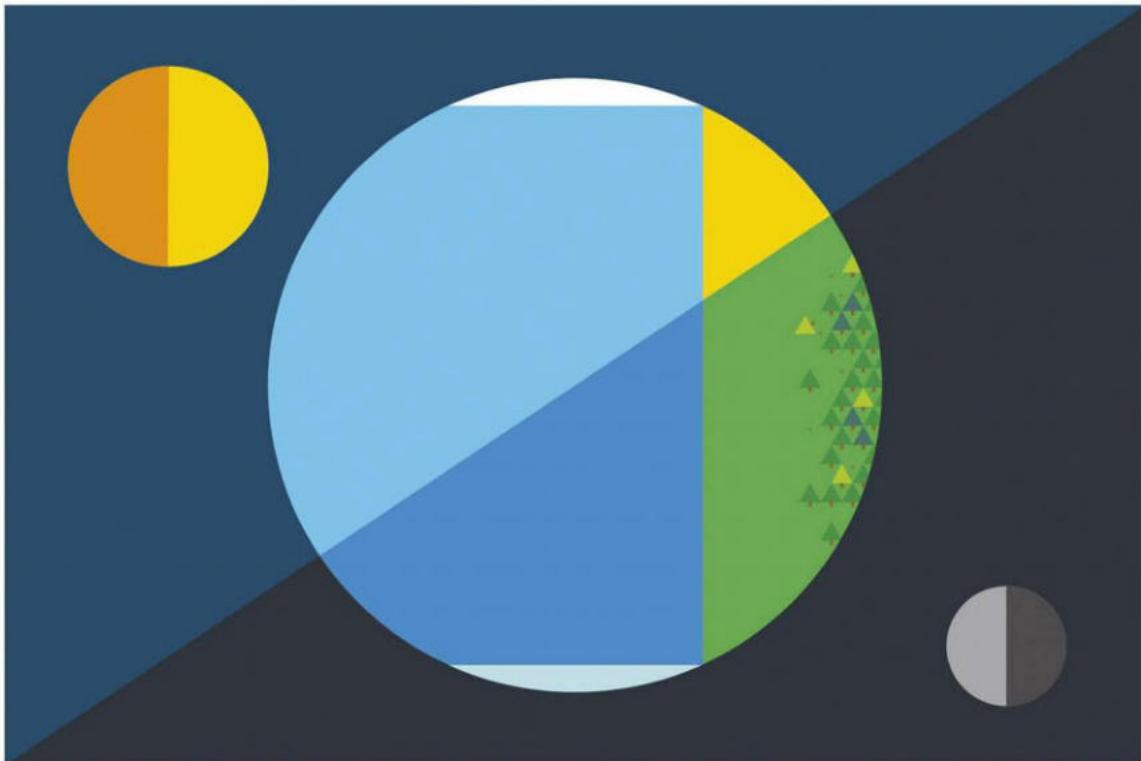
A FLAG FOR PLANET EARTH



Planet Earth needs its own flag! Send your design in to *BBC Focus* and you could win a fabulous prize!



here are some 196 countries on Earth, each with their own flag, yet there is no flag to represent the planet as a whole. With missions to other planets now becoming almost routine, and Earth Day just around the corner, the *BBC Focus* team thinks it's time to set this right and we are asking for your help. What design would you want to see on a flag for planet Earth? We recognise this is a tough task, so we asked luminaries from the worlds of science and design for their ideas to help you get your creative juices flowing.



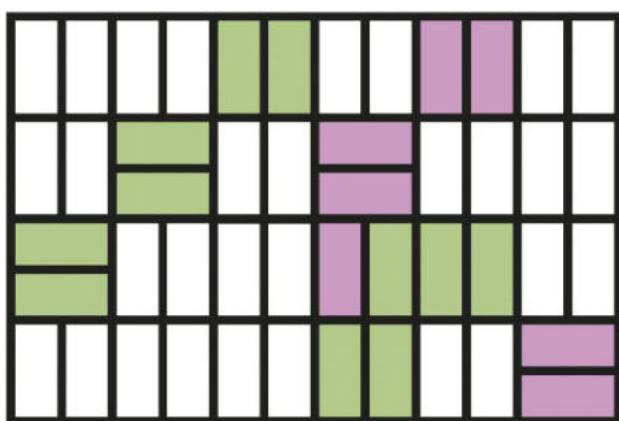
TIM RUFFLE

COMMERCIALS DIRECTOR
AT AARDMAN ANIMATIONS

I wanted to show the world as a flat illustration because you can never see all of the components on one side of the planet. The flat circle represents the Earth and it is divided up to represent the

different parts that make up the planet. The surface water fills 71 per cent of the circle, land fills 29 per cent, 33 per cent of the land is desert, 9 per cent is the Antarctic etc. It's kind of like an informal pie chart. The Sun and Moon are there to show that we have night and day. The idea was that it shows all of the things that make

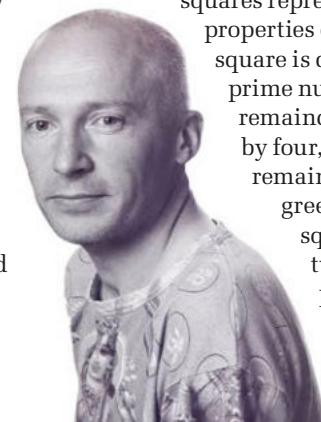
the Earth work and keep it ticking. I decided not to show any countries so that it isn't political. If you look closely you can see that some of the trees are just stumps. That's so you can see the human impact on the trees and see that they are diminishing thanks to logging and deforestation.



MARCUS DU SAUTOY

PROFESSOR OF MATHEMATICS AT
THE UNIVERSITY OF OXFORD

Carl Sagan's sci-fi novel *Contact* chooses prime numbers as the way for his aliens to contact the Earth. These numbers have a universal character that transcends cultural, political and even galactic boundaries. I recently worked with an artist called Richard Rhys who runs a wonderful project called Pattern Foundry. We developed an artwork using prime numbers, and adapted it to make a flag.



It is based on something called the Ulam Spirals. The grid represents the numbers from one to 24 (each number is a square divided into two) arranged in an anticlockwise spiral starting from the middle of the flag outwards. The prime numbers are then coloured in as you spiral round. The colours and orientations of the squares represent different

properties of the primes. A square is coloured purple if the prime number has a remainder of one on division by four, and green if it has remainder three. The half-green/half-purple square is the number two – the only even prime number.

JIM AL-KHALILI

BBC PRESENTER AND PHYSICS PROFESSOR



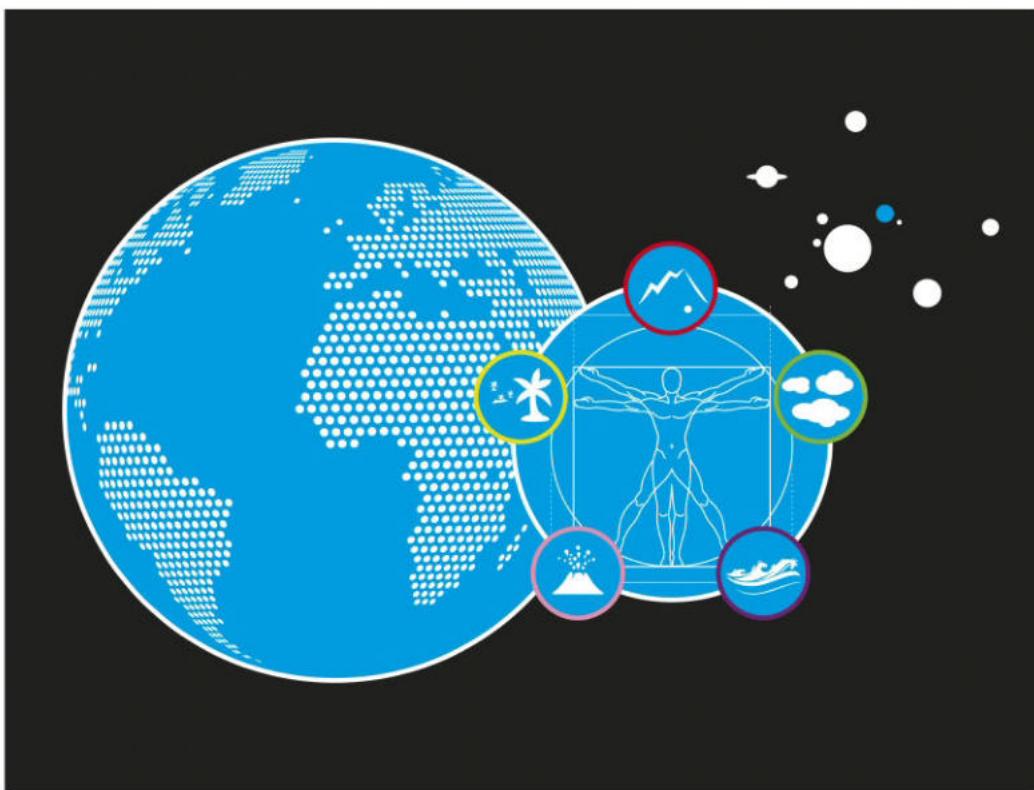
I wanted my flag to convey the beauty of our planet. The most distinctive thing about the Earth as viewed from afar,

certainly within the visible range of the electromagnetic spectrum, is its colours: the blue oceans, green land and white cloud. So I've reflected these in the flag's colours. As for the flag's content, what tugs at the emotional heartstrings of humans is not going to mean anything to an alien civilisation – likewise, with aesthetic beauty. I wanted to choose a design that shows our ability to think, to create, and to imagine: something that's not passive and that could only have been dreamt up by an intelligent, sentient species.



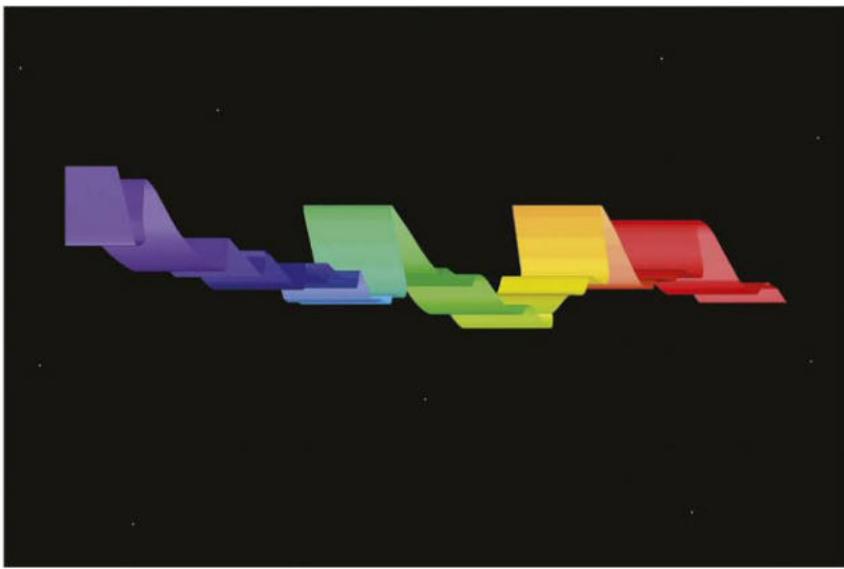
It's no good sticking a mathematical equation down because that uses symbols we invented. Instead, my flag acknowledges our ability to use mathematics by displaying a visualisation of the Mandelbrot

set – a famous example of a fractal. Superimposed inside the fractal pattern are two iconic images that are symbolic of our planet and life within it: a baby in a womb, and an image of the Earth as seen from space.

**HELEN CZERSKI**

BBC PRESENTER AND PHYSICIST

Earth is fascinating because of the five systems it's made up of: the oceans, atmosphere, life, rocks and ice. I'd like a flag that reminds us (and tells any non-Earthlings) that our civilisation can exist because it's got a robust life-support system. We don't stand apart from those five components – they shape us and we're starting to shape them. A flag should represent your identity. The Earth gives us our identity and sets out our place in the Universe.



**FLEUR ISBELL AND
CALLE ENSTRÖM**
DESIGNERS AT BRAND
CONSULTANCY WOLFF OLINS

We've designed a multi-sensory flag that uses sight, sound, smell, touch and taste to represent our species. We didn't want to be limited by a purely visual design. What happens if the

aliens don't have eyes but possess a super sense of smell or hearing?

We used all the colours in the visible part of the electromagnetic spectrum, and each colour is associated with a taste from Earth. So the red part might taste of strawberry; the yellow part of banana.

The flag also uses smells and sounds to communicate. Sound

"For the material, we like the idea of layering solids, liquids and gases. Maybe even jelly, if we want to show that we're playful"



doesn't travel in space, of course, so the sound waves are encoded in the shape of the flag. As the flag moves, smells of the sea, trees, rainstorms and food from Earth are released.

The flag could be hundreds of miles long. For the material, we like the idea of layering solids, liquids and gases. Maybe even jelly, if we want to show that we're a playful species...

BBC SKY AT NIGHT MAGAZINE



A flag for Earth should state our place in the Universe – what better way to

show that than through the stars. The constellations that we know so well are unique to us. In no other sky could you see the great bear of Ursa Major in the north, or the centaur archer of Sagittarius in the south.

The eight circles represent all the currently known planets of our Solar System. Though each is separate and different, all are linked together by gravity, forming one system. Together with the constellations, this creates a map of Earth's place in the Galaxy.

The green band represents not only the ground but also all the life that can be found here, which is undoubtedly Earth's defining feature in the Universe. Above that lies a thin white line representing the atmosphere, separating us from the infinite blackness of space.



HOW TO ENTER Now you've seen our experts' ideas, what would your flag for planet Earth look like? Create your own and submit it to us at bit.ly/PlanetEarthFlag for a chance to win a Nikon Coolpix P900 (RRP £499.99). Entrants must be over 13, and based in the UK. The competition closes 13 May 2016. Full terms and conditions online.

The P900 comes with an 83x optical zoom, GPS and even includes Moon- and bird-watching modes. It's an ideal device for budding astronomers and naturalists.

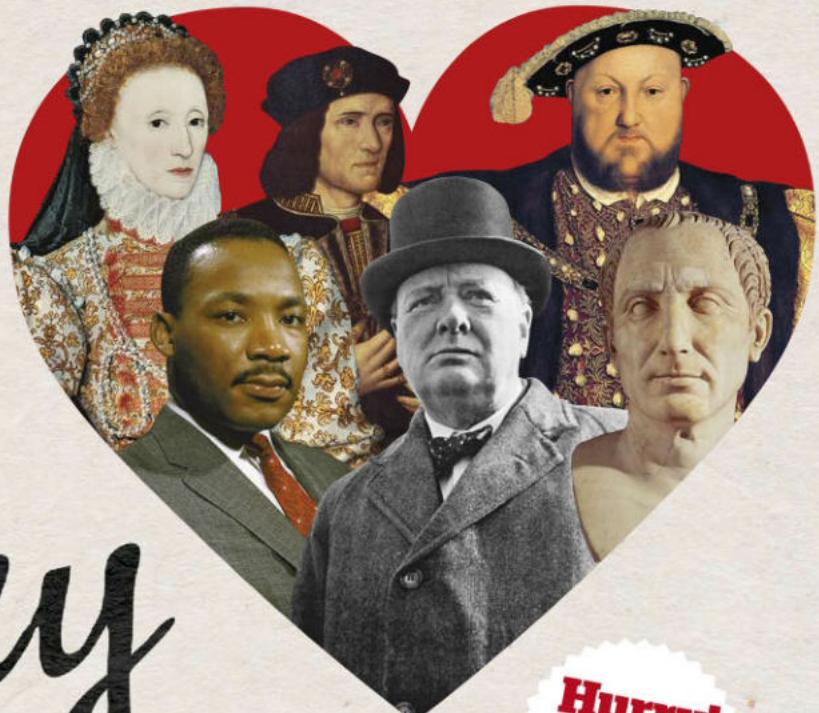
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+ Calls will cost 7p per minute plus your telephone company's access charge. Lines are open 8am-8pm weekdays & 9am-1pm Saturday.

We hope you are enjoying the new look version of *BBC Focus*. As we value our readers' feedback and input we would like to invite you to take part in our 2016 reader survey. As well as providing us with information about the best editorial direction, the results of the reader surveys help us work out what sort of reader offers, advertising and promotions are most relevant to you. In short, the more we know about your interests, likes and dislikes, the more enjoyable we can make *BBC Focus* for you.



Fill in the form below or complete it online at www.sciencefocus.com/readersurvey

A. MAGAZINE READING

1. How often do you read *BBC Focus*?

Always – I subscribe

Always – every issue, but I don't subscribe

Quite often – once every 2-3 issues

Occasionally – once every 4-13 issues

This is my first issue

1
 2
 3
 4
 5

2. How long have you been reading *BBC Focus* for?

Less than a year (go to Q4)

Between 1 and 2 years

Between 2 and 5 years

Between 5 and 10 years

More than 10 years

1
 2
 3
 4
 5

3a. Compared to a few years ago, are you buying *BBC Focus*:

More often

Less often

Same as always (go to Q4)

1
 2
 3

3b. Please explain why you are buying *BBC Focus* more or less often now?

4. On average, how long do you spend reading an issue of *BBC Focus*?

Under 30 minutes

Between 30 minutes and 1 hour

Between 1 and 2 hours

Between 2 and 3 hours

Between 3 and 4 hours

Between 4 and 5 hours

More than 5 hours

1
 2
 3
 4
 5

5. Have you ever read the digital edition of *BBC Focus*?

Yes (answer Q6 then go to Q8)

No (go to Q7)

1
 2

6a. What were the reason(s) you chose to read the magazine as a digital edition? Please select all that apply.

I like to read it on the move

1

It's more environmentally friendly

2

It's cheaper than the print version

3

It's easier to read than print

4

I like the digital-only content

5

It looks so much better than in print

6

It's easy to click on the links

7

6b. Is there anything that would increase your enjoyment of the digital version? Please explain in full.

7. Why have you not read *BBC Focus* as a digital edition?

Please select all that apply.

Didn't know about the digital edition

1

Prefer to have the paper version

2

It's not different enough from the print version

3

I don't have a tablet or e-reader

4

I can't find it in the app store

5

I read my friend's copy of the magazine

6

The file size is too big

7

There's no print and digital combined price

8

Other

9

(please specify)

B. SCIENCE AND TECHNOLOGY INTERESTS

8. What do you think about the level of articles that are featured in *BBC Focus*?

Much too academic

1

A bit too academic

2

About right

3

A bit too simplistic

4

Much too simplistic

5

9. Overall, how interesting do you find *BBC Focus*?

Very interesting

1

Quite interesting

2

Not that interesting

3

Not at all interesting

4

10. How interested are you in reading about these topics? Please select one answer per row.

Topic	1	2	3	4	5
Space exploration	<input type="checkbox"/>				
Astronomy	<input type="checkbox"/>				
Artificial intelligence	<input type="checkbox"/>				
Evolution	<input type="checkbox"/>				
Health	<input type="checkbox"/>				
Medical discoveries	<input type="checkbox"/>				
Important theories explained	<input type="checkbox"/>				
Unsolved scientific mysteries	<input type="checkbox"/>				
The human brain	<input type="checkbox"/>				
Emerging energy technology	<input type="checkbox"/>				
The environment	<input type="checkbox"/>				
Time	<input type="checkbox"/>				
The natural world	<input type="checkbox"/>				
Science history	<input type="checkbox"/>				
Science behind current affairs	<input type="checkbox"/>				
Nanotechnology	<input type="checkbox"/>				
Future technology	<input type="checkbox"/>				
Big data	<input type="checkbox"/>				
Theoretical physics	<input type="checkbox"/>				
Materials science	<input type="checkbox"/>				
Places of scientific interest	<input type="checkbox"/>				

11. Here are some things people have said about *BBC Focus*. How much do you agree/disagree?

	Agree strongly	Agree slightly	Neither agree nor disagree	Disagree slightly	Disagree strongly
It's an authoritative publication	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
The new design is appealing	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
It covers a real breadth of science/tech-related content	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
It introduces me to interesting ideas/discoveries	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
It helps me to understand how science will shape the future	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
It's full of surprising facts	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
It gives me a different perspective on scientific issues	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
It fills me with a sense of wonder	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I can't wait to read the next issue	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
It's really easy to read	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
It's more interesting than before	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

12. On a scale of 0 to 10, how likely would you be to recommend *BBC Focus* to others?

Not at all likely	0	1	2	3	4	5	6	7	8	9	10	Extremely likely
	<input type="checkbox"/>											

13. How much did you enjoy this issue of *BBC Focus*?

- Very much**
Quite a lot
Not very much
Not at all
Didn't read this issue (go to Q16)

1
 2
 3
 4
 5

14. Listed below are all the articles in this issue of *BBC Focus*. What was your opinion of each?

Pg	Did not read	Very interesting	Quite interesting	Interesting	Not that interesting	Not interesting	Not at all interesting
10 Eye Opener	<input type="checkbox"/>						
12 Reply	<input type="checkbox"/>						
14 Discoveries	<input type="checkbox"/>						
27 Innovations	<input type="checkbox"/>						
34 Wonders of the drone age	<input type="checkbox"/>						
46 The allergy fallacy	<input type="checkbox"/>						
53 Columnist Robin Ince	<input type="checkbox"/>						
54 Making waves	<input type="checkbox"/>						
60 Survival of the fittest	<input type="checkbox"/>						
67 Columnist Robert Matthews	<input type="checkbox"/>						
68 Is pornography warping our brains?	<input type="checkbox"/>						
76 A flag for planet Earth	<input type="checkbox"/>						
83 Q&A	<input type="checkbox"/>						
95 Columnist Helen Czerski	<input type="checkbox"/>						
96 Understand forensic science	<input type="checkbox"/>						
102 Out there	<input type="checkbox"/>						
107 Science in the city	<input type="checkbox"/>						
114 Life scientific	<input type="checkbox"/>						

16. Below are some examples of suggested topics for *BBC Focus*. Please tell us how interesting you find each one.

Topic

The space age: mind-blowing cosmology and space missions	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Future technology: tomorrow's world today	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
The natural world: making the connections you've never seen before	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Weird and wonderful: head transplants, building an elevator in space	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Everyday science: the hidden wonders in our daily lives	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
You: incredible feats of the human body and mind	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Counter-intuitive wisdom: can the country really be full? Is recycling any good?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

17a. Compared to a year ago, how do you feel about *BBC Focus* now?

The magazine has improved considerably

1

The magazine has improved a little

2

It's more or less the same as a year ago (go to Q18)

3

The magazine has got a little worse

4

The magazine has got considerably worse

5

I haven't been reading the magazine that long (go to Q18)

17b. Why do you think *BBC Focus* has improved/got worse?

Don't know

18. How often do you look at the adverts in *BBC Focus*?

Always

1

Sometimes

2

Rarely

3

Never

4

READER SURVEY

WIN

one of five

amazon.co.uk
gift certificate

Worth £100



19. Below are some recent changes that have been made to BBC Focus. Please tell us your opinion of each.

This change has made Focus...	A lot better	1	A little better	2	No different	3	A little worse	4	A lot worse	5
-------------------------------	--------------	---	-----------------	---	--------------	---	----------------	---	-------------	---

Introducing infographics
in Discoveries

New Innovations section

New Out There section

Changing six-page Megapixel

to two-page Eye Opener

Dropping the Crossword page

20. Has reading BBC Focus ever led you to do any of the following? Please select all that apply.

Visit sciencefocus.com	<input type="checkbox"/>	1
Attend an event/exhibition	<input type="checkbox"/>	2
Buy a tech product/gadget	<input type="checkbox"/>	3
Buy another product	<input type="checkbox"/>	4
Seek more info on a product seen in the magazine	<input type="checkbox"/>	5
Discuss an advert/article with someone else	<input type="checkbox"/>	6
Visit a company's website	<input type="checkbox"/>	7
Contact an advertiser	<input type="checkbox"/>	8
Research an article further	<input type="checkbox"/>	9
Take a course	<input type="checkbox"/>	10
Take a trip to a place of interest	<input type="checkbox"/>	11

21. On average, how often do you visit the BBC Focus website (sciencefocus.com)?

More than once a day	<input type="checkbox"/>	1
Once a day	<input type="checkbox"/>	2
About 2-3 times a week	<input type="checkbox"/>	3
Once a week	<input type="checkbox"/>	4
Once every couple of weeks	<input type="checkbox"/>	5
Once a month	<input type="checkbox"/>	6
Every 2-3 months	<input type="checkbox"/>	7
Less often	<input type="checkbox"/>	8
Never used it	<input type="checkbox"/>	9

22. Do you have any other comments on BBC Focus?

.....

23. What do you want to learn most about this year?

.....

24. Who is your science hero and why?

.....

C. WIDER INTERESTS

25. How often do you read the following magazines?

Magazine	I subscribe	I don't subscribe but I buy every issue	Quite often	Occasionally one issue	Only read
Wired	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Stuff	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
T3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
How It Works	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Wonderpedia	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
New Scientist	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
BBC Sky At Night Magazine	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
National Geographic	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
BBC Top Gear Magazine	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
BBC Wildlife Magazine	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
BBC History Magazine	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Fill in the form above or complete it online at www.sciencefocus.com/readersurvey



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Q & A



DR CHRISTIAN JARRETT

Christian edits The British Psychological Society's Research Digest blog. His latest book is *Great Myths Of The Brain*.



DR ALASTAIR GUNN

Alastair is a radio astronomer at the Jodrell Bank Centre for Astrophysics at the University of Manchester.



PROF ROBERT MATTHEWS

After studying physics at Oxford, Robert became a science writer. He's visiting professor in science at Aston University.



DR PETER J BENTLEY

Peter is a computer scientist and author who is based at University College London.



LUIS VILLAZON

Luis has a BSc in computing and an MSc in zoology from Oxford. His works include *How Cows Reach The Ground*.

YOUR QUESTIONS ANSWERED

Email your questions to questions@sciencefocus.com or post to BBC Focus Q&A, 2nd Floor, Tower House, Fairfax Street, Bristol BS1 3BN.

What happens to the donor's DNA in a blood transfusion?

SUSAN BOWNASS, YELLING

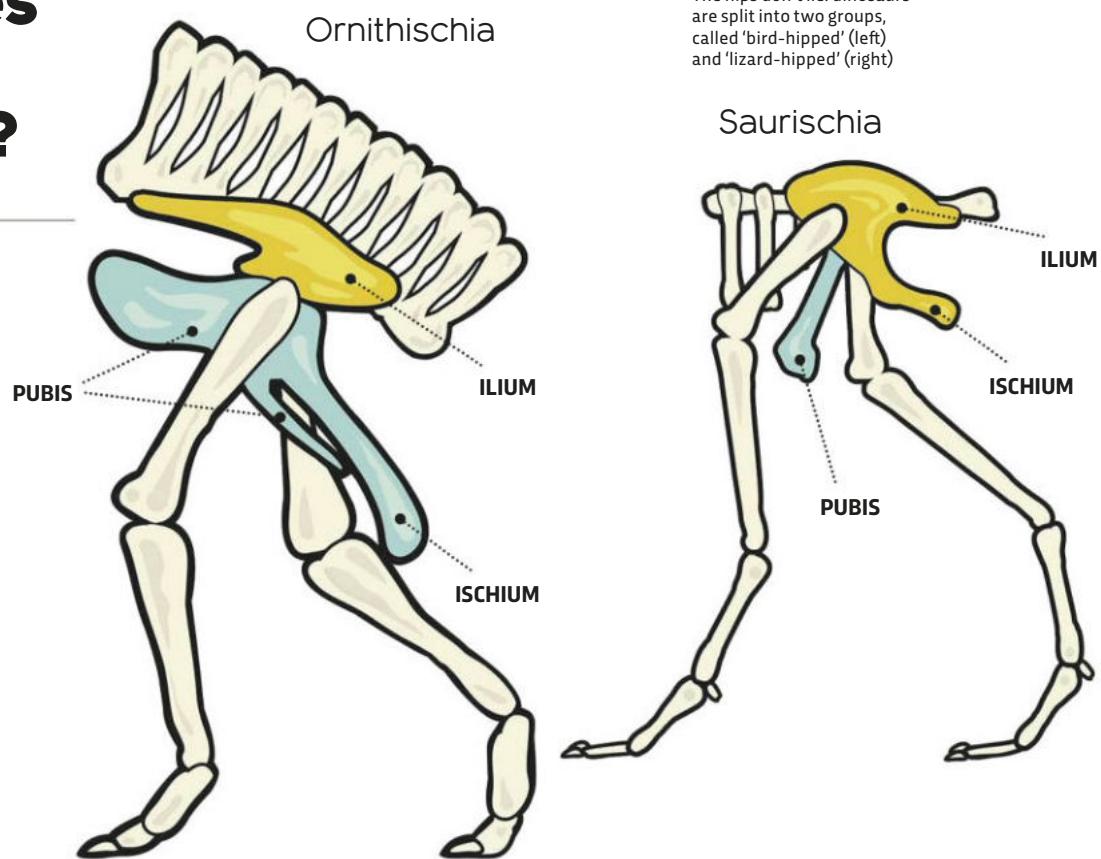
There is virtually none there to begin with. Only the white blood cells have a nucleus, so they are the only cells that carry any of the donor's DNA. Red blood cells and platelets lose their nucleus during production in the bone marrow. Donated blood is spun in a centrifuge to separate it into plasma, platelets, red cells and white cells and only the first three are used for transfusions. If whole blood is used in an emergency transfusion, it causes a fever called 'febrile non-haemolytic transfusion reaction', as the recipient's own white cells destroy the foreign DNA. **lv**

So whole blood makes you ill? No wonder Dracula was so stroppy...

What makes a dinosaur a dinosaur?

MARTIN GREEN, FAREHAM

It's all to do with the shape of the pelvis. Dinosaurs are divided into two groups: the Saurischia, or 'lizard-hipped' dinosaurs, have a pubis bone that points forward; the Ornithischia ('bird-hipped') have a backwards-pointing pubis. Any fossil with either of these pelvis types is classified as a dinosaur. Ironically, birds are actually descended from the Saurischia. Their bird hips evolved independently, much later in time. **LW**



The hips don't lie: dinosaurs are split into two groups, called 'bird-hipped' (left) and 'lizard-hipped' (right)

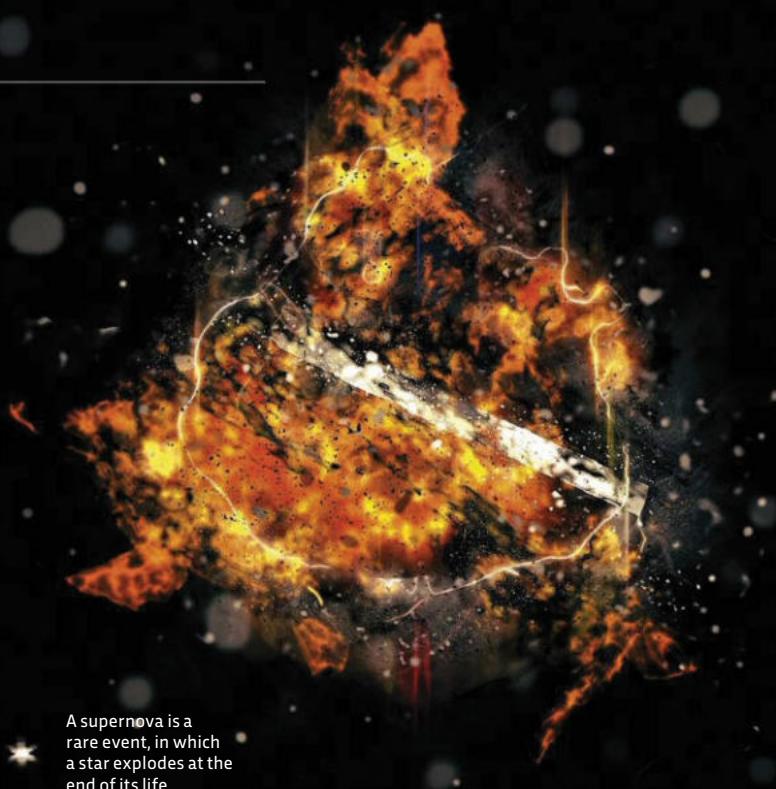
What ignites supernova explosions?

MATT BELL, SOUTHAMPTON

Although there are many classifications of supernovae, there are two basic mechanisms that result in stars blowing themselves apart. The first involves the accumulation of material into a white dwarf star, the extremely dense final evolutionary state of most normal stars. This extra material could come from a merger with or by simple accumulation from a close companion star. As this material accumulates on the white dwarf, its core temperature increases until a runaway nuclear reaction occurs. In a fraction of a second most of the white dwarf

undergoes nuclear fusion, blowing the star apart in the process.

The other way a supernova can 'ignite' is by the collapse of a high-mass stellar core. As the star reaches the end of its life the nuclear fuel becomes exhausted, the energy source switches off and the pressure holding the star up against gravity disappears. The core collapses almost instantaneously, causing a catastrophic release of energy that destroys the star. If the core mass is high enough, however, the star may become a neutron star or black hole with little radiated energy. **AG**



A supernova is a rare event, in which a star explodes at the end of its life

IN NUMBERS

30
metres

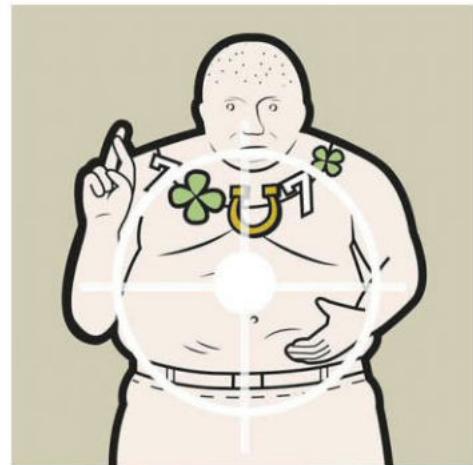
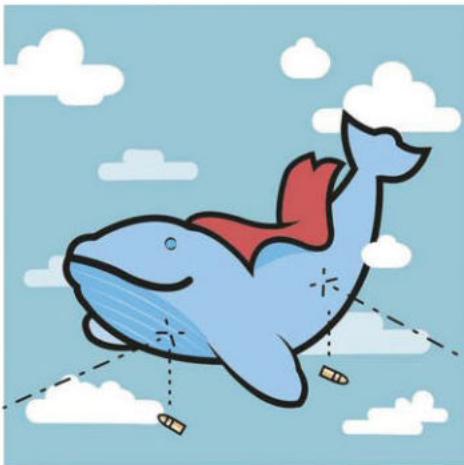
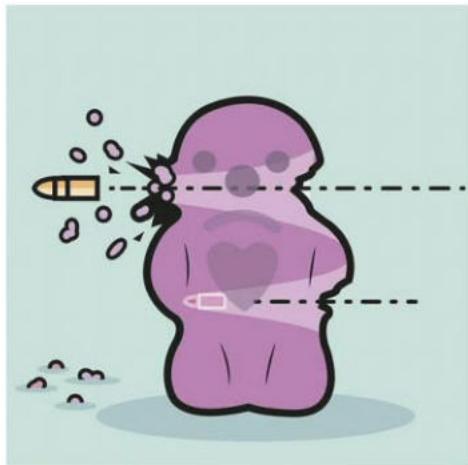
is the height
of the biggest wave
ever surfed

20

teeth are present in the
mouth of a common
vampire bat – the fewest
number of teeth of any
bat species

THE THOUGHT EXPERIMENT

HOW FAT DO YOU HAVE TO BE TO STOP A BULLET?



1. IT DEPENDS ON THE GUN

Experiments using ballistic gelatine to mimic the human body suggest that a 9mm bullet from a handgun will penetrate about 60cm through human fat tissue. A fully jacketed bullet from an assault rifle, such as an AK-47, will go much further and can easily shoot through a brick wall.

2. NOBODY IS THAT FAT

A morbidly obese person weighing over 125kg might have 60cm of fat at the thickest point, including subcutaneous fat and the fat that surrounds their organs. But no one has that thickness evenly across their entire body. Even a blue whale's blubber is only 30cm thick.

3. DO YOU FEEL LUCKY?

In 2010 Samantha Lynn Frazier was hit by a stray bullet in a shooting in Atlantic City, New Jersey. The bullet lodged in her 'love handles' and she was otherwise unharmed. This is rare, though, and we can't know for sure whether the bullet ricocheted off something else before it struck her!

Could my pet catch my cold?

DEBBIE REES, LEICESTER

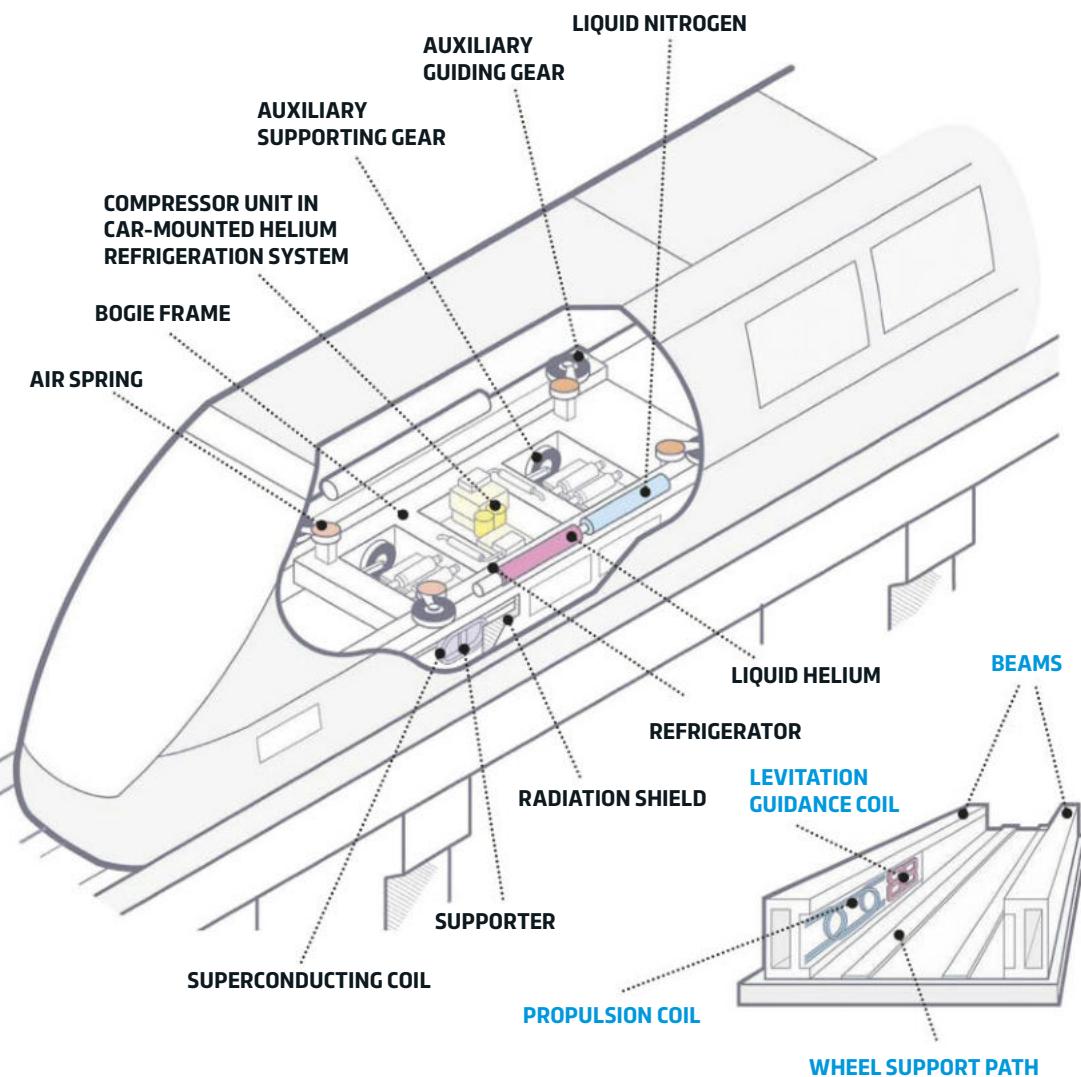


The viruses that cause ordinary colds are all quite species-specific. Dogs can't catch human colds (or vice versa), but they do have their own version, called canine infectious tracheobronchitis or kennel cough. The influenza virus is much more adaptable though. Bird, pig, horse, dog and human flu have all been shown to jump the species barrier. And bacterial diseases are even more contagious. Cats and dogs can both catch tuberculosis from humans, for example. **LV**

EDS MAGLEV

There are two main types of maglev train that use magnetism in different ways. Electromagnetic suspension (EMS) uses C-shaped arms that wrap underneath the track. Electromagnets on the underside pull the train up by attracting the arms to the bottom of the track.

Electrodynamic suspension (EDS), pictured here, uses the train's motion to induce magnetic eddy currents in the metal rail, which creates a cushion of magnetic repulsion. The sides of the track have magnetic coils built in, which create an overlapping pattern of alternating north and south magnetic fields. To accelerate, the train rapidly alternates the direction of its own supercooled magnetic coils to attract the front of the train to the next coil along the rail.



How long will the man-made objects on the Moon last?

STEVE CAMERON, BY EMAIL

It has been estimated that there are more than 180 tonnes of man-made material on the Moon, ranging from bags of human body waste to crashed spacecraft. But there is very little to affect this material – no wind, pollution or water to erode, rust, dissolve or abrade it – although the action of sunlight, particularly UV radiation, has probably already bleached the US flags left there by the Apollo astronauts. While the constant bombardment by energetic micrometeorites is likely to gradually erode this material over time, current research suggests it could survive for up to 100 million years! AG



PHOTO: NASA. ILLUSTRATION: PHIL ELLIS

What happens to lost body fat when we lose weight?

TERRY HONEYWOOD, BROMLEY

Fatty acids are broken down into smaller molecules and fed to the 'power plants' of our cells, the mitochondria (pictured)



Our fat is stored as triglycerides. When we need it for energy, enzymes in the blood break it down into fatty acid chains and glycerol. The fatty acids are absorbed by cells and broken down into even smaller molecules and 'fed' to our

mitochondria (the 'power plants' of our cells). The ultimate waste products of this complex sequence are just CO₂ and water, which we breathe out. So when you exercise, you are turning fat into puffing and panting. **lv**

Why do sneezes come in twos or threes?

TOM ENGLAND, LIVERPOOL

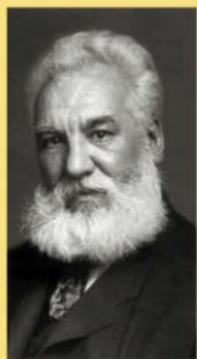
Sneezing is a way for your body to reset the nasal environment by getting rid of any irritating particles and restoring the correct level of mucus – either too much mucus or too little can trigger a sneeze. For a single sneeze to guarantee to shift any possible irritant, it would have to be dangerously powerful. Sneezes already expel air at 160km/h (100mph), so it's safer to just chain a few sneezes together if the first doesn't do the job. **lv**

PHOTO: ISTOCK/GETTY X2



WHO REALLY INVENTED...

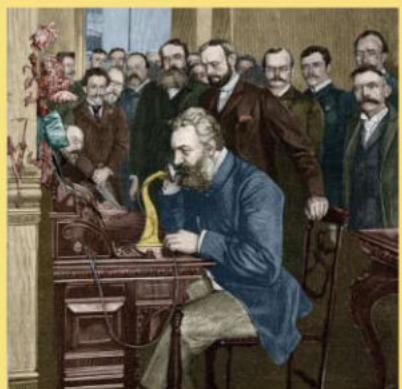
THE TELEPHONE



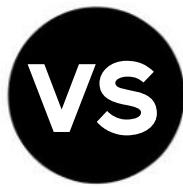
ALEXANDER GRAHAM BELL

ANTONIO MEUCCI

Credit is usually given to the Scottish-born scientist and engineer Alexander Graham Bell, who was granted a US patent for what he called an 'acoustic telegraph' in 1875. His claim comes complete with the famous story of Bell using his invention to call his colleague in the next room with the words: "Mr Watson, come here – I want to see you." Yet like many major inventions, whether Bell deserves all the credit has long been the subject of debate, not least over what exactly constitutes a 'true' telephone. For example, some historians point out that Italian engineer Antonio Meucci and German inventor Philipp Reis independently invented telephone-like devices that achieved the key breakthrough of turning sound into electric signals over a decade before Bell. In 2002, the US House of Representatives accepted that Meucci's work was so important that it could have been enough to prevent Bell getting a patent. Over the years, Bell's right to any credit has been challenged by evidence that he plagiarised key parts of his design.



HEAD TO HEAD

**UK SMOKERS****UK DRINKERS**

10	NUMBER OF (millions)	24
----	-----------------------------	----

£9.5bn	TAXES RAISED (per yr)	£10bn
--------	------------------------------	-------

£2bn	COST TO NHS (per yr)	£3.5bn
------	-----------------------------	--------

450,000	HOSPITAL ADMISSIONS (yr)	1,100,000
---------	---------------------------------	-----------

100,000	DEATHS (yr)	6,600
---------	--------------------	-------

Which is worse - smoking or drinking? As an individual, cigarettes are much more likely to kill you eventually, but alcohol can kill you at any age; through binge drinking, alcohol-

related violence and drink driving. And smoking rates have almost halved since 1974, whereas average alcohol consumption figures have fallen much more slowly.

Can microwaves change the molecular structure of food?

DONNA KIDDIE, NORTH AYRSHIRE

Yes. When you microwave a piece of chicken, energy from the microwaves causes the protein molecules to vibrate faster. This can break the hydrogen bonds and sulphur bridges that give the protein chains their specific three-dimensional shape. With a piece of bread, a high enough dose of microwaves will cause the starch and protein molecules to break down and react with each other to create dozens of complex organic molecules.

When you put food under the grill, you are cooking it with infrared waves, which are part of the electromagnetic spectrum – just like microwaves. The difference is that infrared rays have a longer wavelength that doesn't penetrate as far



into the food. Most of the energy therefore gets deposited at the surface of the food, which gets brown and crispy. Microwaves tend to spread their energy more evenly throughout the food, so it cooks before the outside becomes brown, but the basic chemistry is much the same. There are no chemical reactions unique to food cooked in a microwave. **LW**



Why are some people so hairy?

JENNY LUND, PRESTON

Hair growth in humans is complicated and influenced by several different genes and hormones. The prevailing theory is that we evolved to have less hair than primates because our ancestors evolved sweating as a strategy to keep cool on the African savannah, and too much hair gets in the way of sweating. But the evolutionary reasons why hairiness varies with ethnicity are unclear. Caucasian people are generally hairier than the Japanese, for example, even though testosterone levels are the same. The difference seems to be in how sensitive the hair follicles are to those testosterone levels. **LW**



'Werewolf syndrome', or hypertrichosis, causes thick hair to grow over the body



Why do we talk in our sleep?

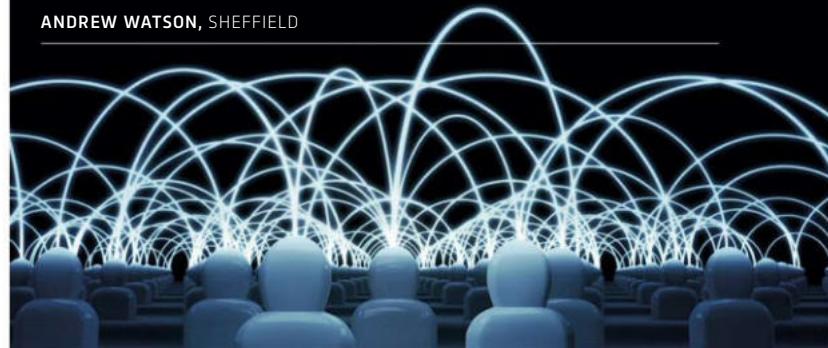
CATHERINE FLIND, CIRENCESTER

When we are sleeping, there is a brain mechanism that stops the neural activity associated with dreaming from triggering speech or body movements. But this system isn't perfect, and sometimes signals can get through. This can lead to mumbling and groaning and sometimes even proper speech (and sleep walking).

The content of sleep talking can be complex and is usually grammatically correct. It may be influenced by recent events in the sleeper's life, but can be strange and nonsensical. Sleep talking is usually benign, although stress and other psychological problems can increase the likelihood of it occurring. **CJ**

Are public Wi-Fi networks safe?

ANDREW WATSON, SHEFFIELD



No Wi-Fi network is completely safe if you have the wrong settings on your phone or computer. When you browse http pages, you are transmitting and receiving unencrypted text; this makes it easy to intercept, making your passwords vulnerable. Only https pages are secure. If you have Sharing

enabled on your computer, it is possible to access your files or even remotely log on to your system. For these reasons it's best to keep Sharing switched off, your Firewall turned on, and do not browse sensitive websites on public networks. If you have to do so regularly, you should use a Virtual Private Network (VPN). **PB**

What's the difference between viruses, trojans and worms?

SIMON RANKIN, MAIDSTONE

A virus is a nasty piece of software that is inserted into a normal piece of software, just as a biological virus infects a cell. When the normal software is run, the virus copies itself into other software while also doing unwanted things such as recording keystrokes to steal passwords. A trojan is similar, but it does not replicate itself. It hides inside a seemingly innocuous program – run the program and the trojan wreaks havoc, from deleting your files to giving hackers access to your system. A worm is an independent program that replicates on its own, typically spreading across networks and causing major disruption to systems. **PR**



WHY DO PLANES HAVE TO BE 'DE-ICED'?

DAN PYCROFT, EXETER

Planes are designed to cope with extremes of temperature, allowing them to take off from searingly hot desert runways before cruising in the bitter -55°C cold of the stratosphere just minutes later. Yet even the most sophisticated aircraft can be put at risk by freezing conditions. When ice builds up along the leading edges of the wings it changes their shape – and thus their ability to generate lift.

Aircraft are fitted with de-icing systems, but in severe conditions even these can be inadequate, requiring the application of high-pressure blasts of antifreeze. Failure to use them can be disastrous. In 1982, ice on the wings of a Boeing 737 taking off from Washington DC prevented it from climbing adequately. It crashed into the frozen Potomac river, killing 74 passengers and crew. **RM**

WHAT CONNECTS...

...FRIDGES TO FRYING PANS



1.

Chlorofluorocarbons (CFCs) are organic molecules with a low boiling point. Before they were discovered to deplete the ozone layer, CFCs were widely used as the refrigerant gas in fridges.

2.

The company that first used CFCs in fridges was Kinetic Chemicals, owned by General Motors and DuPont. They trademarked their particular blend of CFC compounds as 'Freon' (pictured) in 1930.



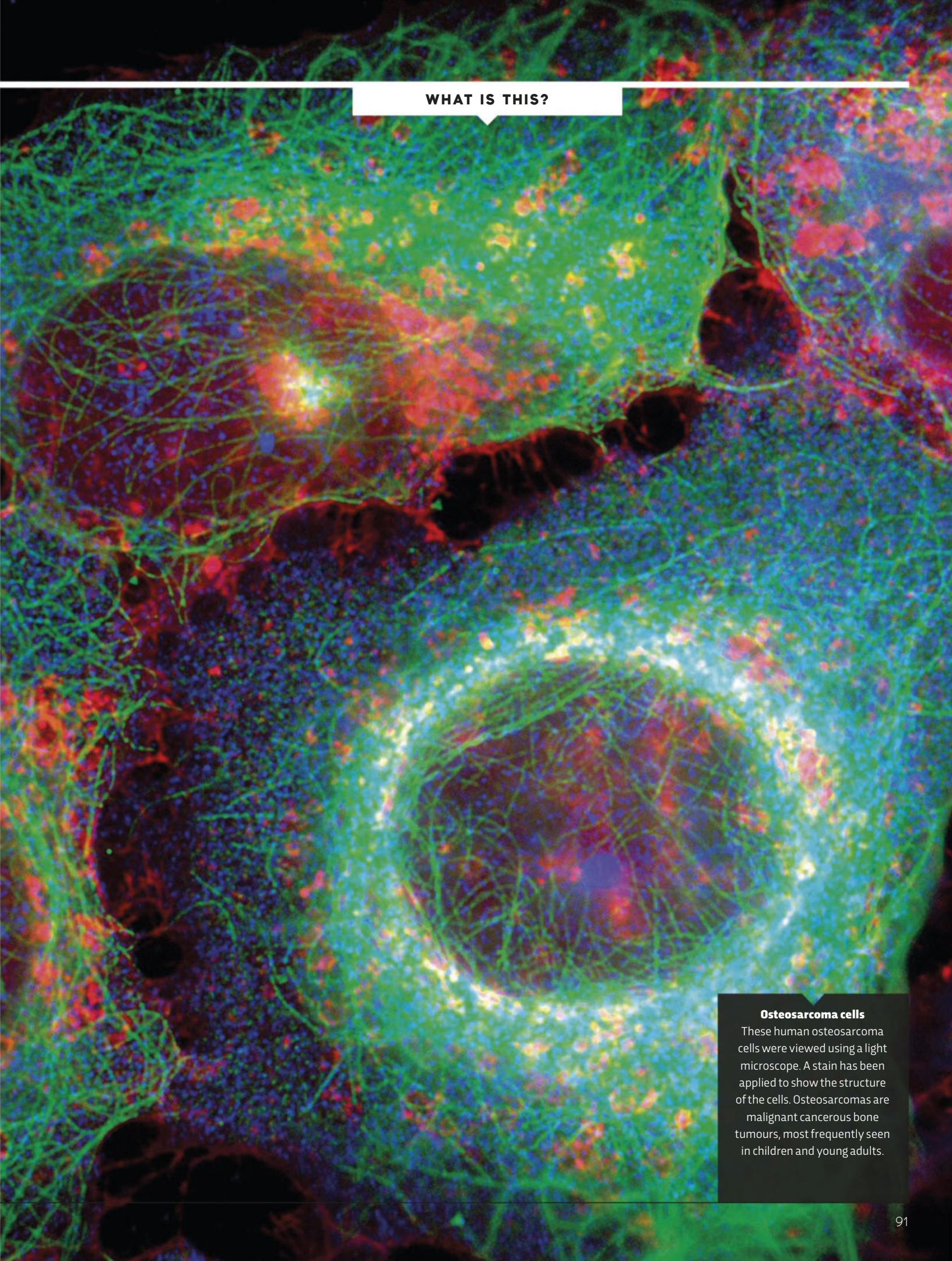
3.

In 1938, a DuPont researcher called Roy Plunkett found his gas cylinders of the CFC tetrafluoroethylene were clogged with a white slippery substance. The iron cylinder was catalysing the CFC into polytetrafluoroethylene (PTFE).

4.

DuPont trademarked PTFE as Teflon. It wasn't until 1954 that French engineer Marc Grégoire tried using it as a non-stick coating on frying pans. The company Tefal was named after 'Teflon' and 'aluminium'.





WHAT IS THIS?

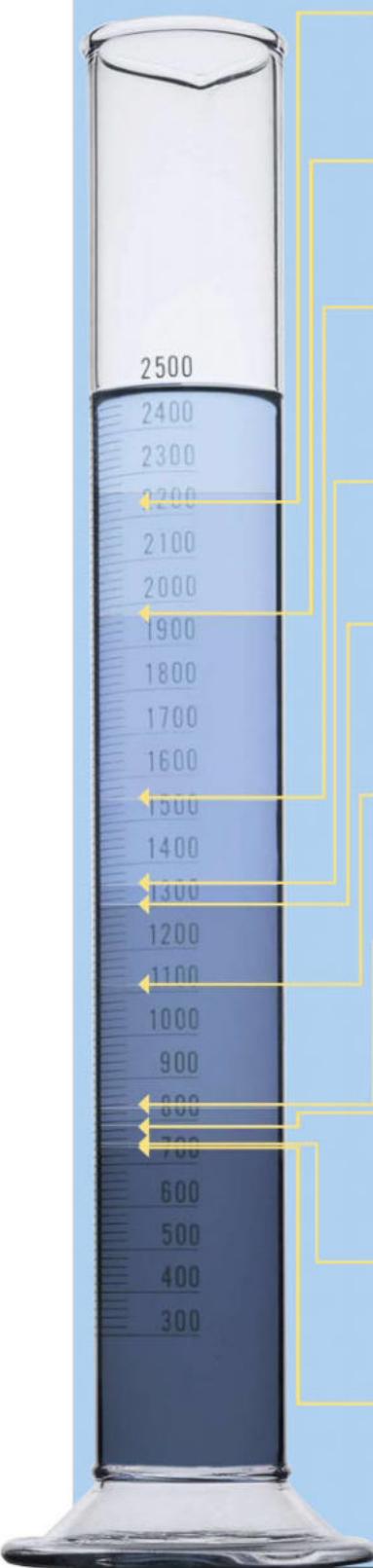
Osteosarcoma cells

These human osteosarcoma cells were viewed using a light microscope. A stain has been applied to show the structure of the cells. Osteosarcomas are malignant cancerous bone tumours, most frequently seen in children and young adults.

TOP 10

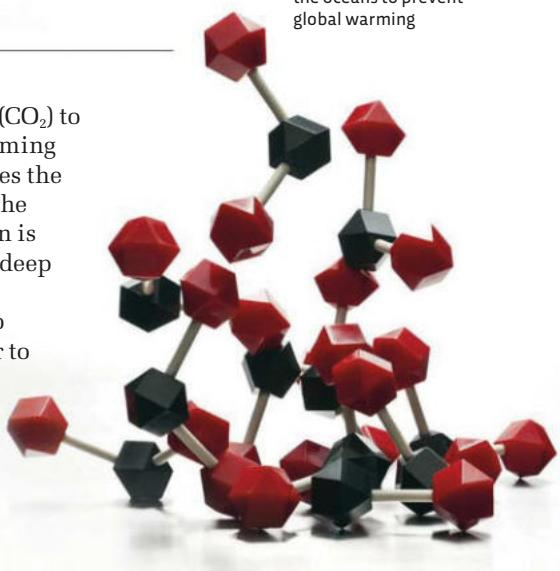
TOP 10 WETTEST REGIONS OF THE UK IN 2015

Source: The Met Office
metoffice.gov.uk/climate/uk/summaries/2015/annual/regional-values

Could captured CO₂ be stored in the deep ocean?

MARK COOPER, MANCHESTER

Capturing carbon dioxide (CO₂) to stop it boosting global warming seems a good idea, but raises the problem of where to store the stuff. One low-cost solution is simply to pump it into the deep ocean, but CO₂ is toxic to marine life and would also combine with the seawater to produce an acid, which would pose unknown environmental risks. Underground or sub-seabed storage are thought to be less risky options. RM



We can't just chuck carbon dioxide into the oceans to prevent global warming

Why does garlic give you bad breath?

ALISON SMITH, LONDON

Garlic contains a chemical called allyl cysteine sulphoxide or 'alliin'. When a raw garlic clove is crushed or chopped, an enzyme in the garlic cells is released that reacts in a matter of seconds with the alliin to produce a chemical called allicin. This breaks down into lots of other chemicals, most of them stinky. Nearly all of these chemicals are broken down in your stomach and liver, but allyl methyl sulphide is one that survives to be absorbed

into the bloodstream intact. This means that it can diffuse out through your lungs into the air you exhale for up to two days. Brushing your teeth has only limited effect because the chemical is still in your blood. LV

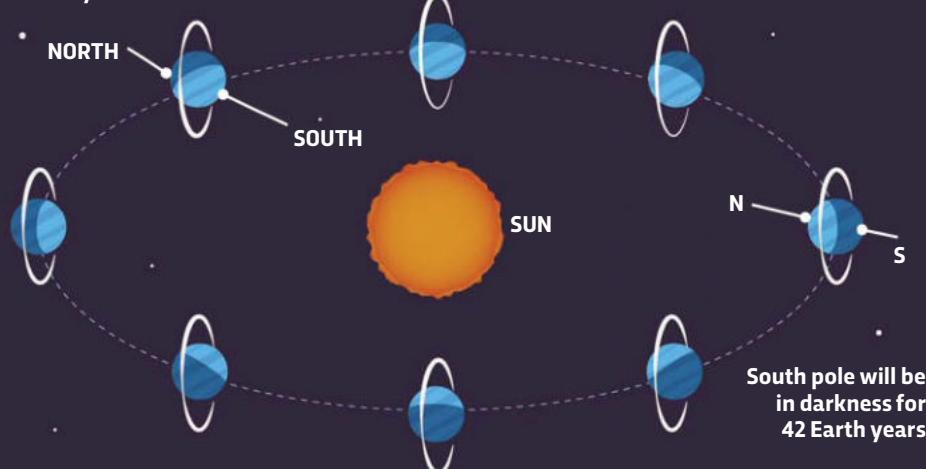


QUESTION OF THE MONTH

Why does Uranus orbit the Sun on its side?

FINN GAPE, KENT

South pole will be in sunlight for 42 Earth years



WINNER!

Congratulations to Finn Gape who wins a pair of Momentum In-Ears, (£8999, en-uk.sennheiser.com).



The reason for this is not known for sure. The most likely cause is that Uranus collided with a large object soon after its formation. The problem with this explanation is that if the planetary system were disrupted by a single impact it would result in the moons of Uranus having 'retrograde' orbits (orbiting in the opposite direction to the spin of the planet). However, this is not what is observed. Encouragingly, the latest research suggests that two or more impacts with Earth-sized protoplanets could result in exactly the kind of orbits displayed by Uranus's moons. AG

IN NUMBERS

300
hours

of video are uploaded to YouTube every minute

35
metres

is the height of the tallest Lego structure – it was built outside St Stephen's Basilica in Budapest and contains around 450,000 bricks

After 10 days of going cold turkey, James was now 48 hours into his nose-picking binge

Why are habits so hard to break?

LOUISE COE, BICESTER

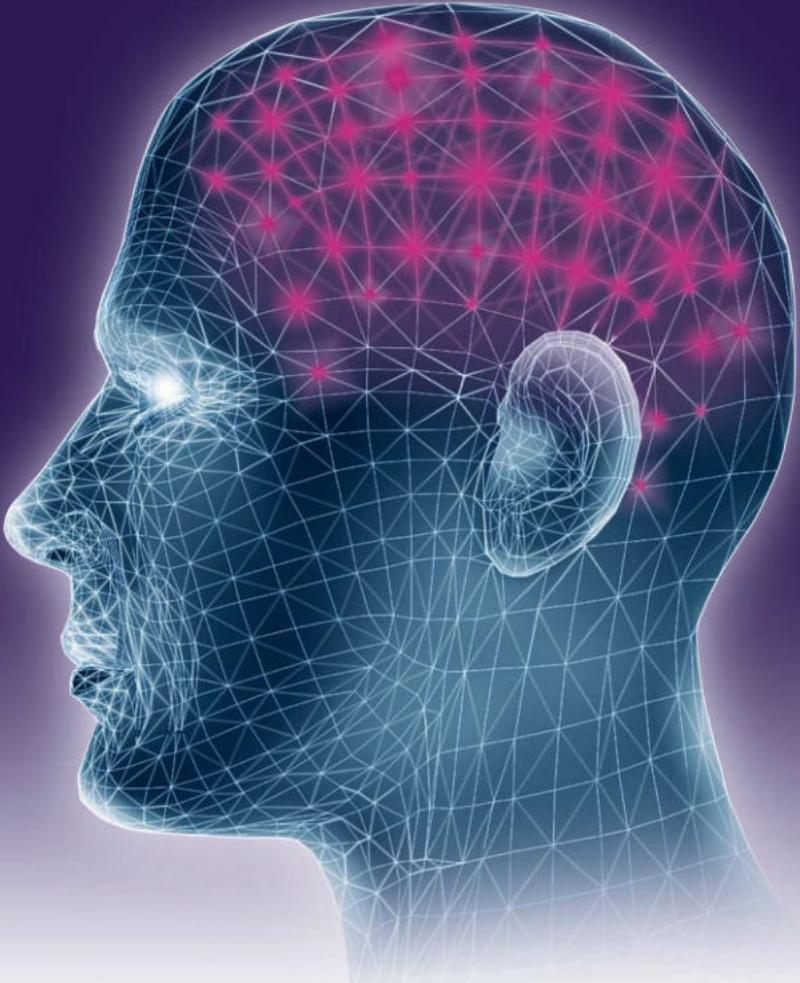


Habits are behaviours that we perform automatically, especially in response to a prompt, such as a particular place or time of day. They're so tricky to break because they usually happen without any thought, a bit like a reflex. One solution is to identify the trigger that cues your habit, and either avoid it somehow (for example, don't leave the biscuit tin out on display), or plan in advance an alternative action, known as an 'if-then plan', such as "If I see a croissant in the cafe, then I will buy an apple instead." Easier said than done! q

NEXT ISSUE:

Did eyes or ears evolve first?
Do offices make us sick?
Is there life in clouds?

Feed your mind

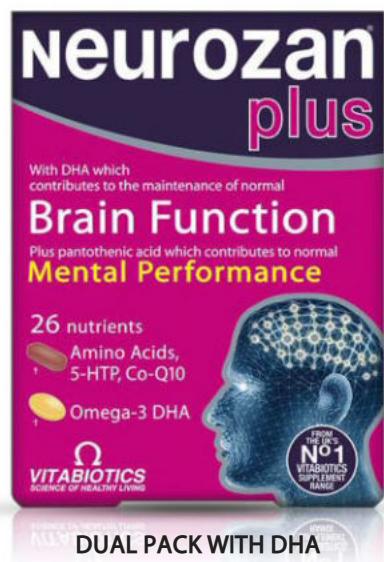


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From Waitrose,
Holland & Barrett, supermarkets,
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[†]A beneficial effect is obtained with a daily intake of 250mg DHA.
*Nielsen GB ScanTrack Total Coverage Value Sales 52 w/e 25th April 2015.



VITABIOTICS
SCIENCE OF HEALTHY LIVING



HELEN CZERSKI... SELF-STIRRING SHAMPOO

"TAKE A MOMENT TO THINK ABOUT THE FLUID IN YOUR BATHROOM, SHIFTING IN A SLOW WALTZ"

When I was an undergraduate, one of my lecturers told tales of the geological discoveries that had been made by accident, of the many times when someone saw something odd but important while they were supposed to be focusing on something else. This is one of the strongest arguments for carrying out experiments, rather than just thinking about problems. You never know what the world is about to show you. This month, I did a demonstration for my students that turned out to be much more interesting than I'd expected.

I spend far too much time in shops tilting bottles of shampoo to assess how slowly the liquid flows. That's because buying colourless shampoo is a quick and easy way of gathering a range of viscous fluids for simple demos. For this particular demonstration, I'd filled a large glass jar with very gloopy transparent shampoo and floated a plastic ball in it. I scribbled on the outside of the plastic ball with black marker pen to demonstrate a point about buoyancy. After the lecture, I left the jar sitting on a table in my office.

After it had been there for two days, I noticed that a blob of marker pen ink was moving away from the ball. As the days went on, I watched the black streak advance downward and then around in circles, moving perhaps a couple of centimetres each day. After two weeks, the jar contained a large whirl, stretching around in spirals, reaching right to the bottom of the jar and back up, using all of the three dimensions available to it. The conclusion was inescapable: although the transparent gloopy stuff looked as though it was just sitting in a jar doing nothing, it was actually moving.

The explanation must be convection. Heating any liquid will cause it to expand slightly. If the heated fluid is below a cooler fluid, it becomes buoyant and will rise. The temperature in my office varies because the university building is only heated during the day. In the evenings and at weekends, it's cooler. That's one part of the explanation – the overall temperature is rising and falling.

The other question is how the convection is driven. Is the shampoo at the top cooling in the evenings and sinking? Or, in the mornings, is the shampoo getting



This month, a humble bottle of shampoo took Helen on an enlightening journey

heated up from below and rising? There are clearly more experiments to be done!

But what really got me thinking is the implication that all those bottles of shampoo and shower gel in my bathroom are presumably also moving. The movement is really slow, firstly because the fluid is so thick that it will only gradually respond to a temperature imbalance. And secondly, the density changes caused by the different temperatures within a single bottle are tiny, so they won't provide much push. But my

bathroom cupboard also follows a daily temperature cycle, and so all the gloop in there is presumably also swirling slowly around, even if it's been neglected for years.

So next time you open your bathroom cupboard, take a moment to think about the fluid in there shifting around in a slow waltz, responding to the outside world even though it's sealed in. Shampoo is never going to look quite the same again. ♪

Dr Helen Czerski is a physicist and BBC science presenter whose most recent series was *Colour: The Spectrum Of Science*.

DISCOVER MORE

Did you miss *Colour: The Spectrum Of Science*? You can buy all three episodes of the series in the BBC Store at store.bbc.com

NEXT ISSUE: SCIENCE OF STALING



CRIME SCENE INVESTIGATION

'Forensics officers' are a crime show staple, but how does the work they really do match up to what we see on our TV screens?



UNDERSTAND FORENSIC SCIENCE

Scene-of-crime operatives in plastic overalls are a common sight on our TV screens. But what do they actually do?

WORDS: TOM IRELAND

What is forensic science?

Any scientific process used as part of a criminal investigation is considered forensic science. This spans both the grim, grisly procedures of the autopsy room and the cutting-edge analysis of a crime scene. But it also encompasses the less glamorous, painstaking lab work of DNA profiling, fingerprint analysis and the uncovering of hidden digital files. There is even such a thing as forensic accountancy.

What techniques are used to solve crimes today?

The bulk of modern forensic work involves the analysis of DNA or fingerprints left at a crime scene. In murder cases, forensic autopsies help work out how a person died.

A range of more specialised and elaborate forensic techniques can be used to identify suspects in the most serious cases, such as tracking serial killers or terrorists. These methods include forensic ecology, where tiny traces of pollen or fungal spores can be used to tell where a suspect has been, or forensic entomology,

where the presence of certain insects can help reveal how long a person has been dead.

As people spend more and more time on devices like smartphones and computers, so-called 'digital forensics' is playing an ever-greater role in criminal investigations, too. The growth in this field of forensic science also reflects the fact that there are now over four million CCTV cameras in the UK.

Is forensic science anything like what we see on TV?

Rarely. According to forensic scientist Prof Sue Black, who has advised a number of crime writers throughout her career, "There is an element of truth in TV crime, but also an element of fantasy – the work is often long, slow, and laborious. But viewers quite rightly don't want to see us doing our double-blind trials."

Nathan Clarke, a professor of digital forensics and cyber security, says the depiction of tracking technology in spy movies, where security services miraculously enhance fuzzy images of suspects, is pure



Forensic science isn't as glamorous as television shows suggest...



← Even a tiny sample of DNA can provide crucial evidence

fiction. "In reality, you need someone to sit there and watch hours of video," he says.

How does DNA profiling work?

Although 99.9 per cent of our DNA is the same in every person, the remaining 0.01 per cent is different enough to distinguish one individual from another.

Forensic DNA profiling looks specifically at highly variable stretches of DNA called 'variable number tandem repeats' (VNTRs). These are short sequences of genetic code that may occur tens or hundreds of times at specific points in a person's DNA.

VNTRs are often located in parts of the human genome with little or no known function. Mutations in the genetic code here will not cause abnormalities, and so over many generations these sections of our genome have become hugely varied. And because unrelated people will almost certainly have different numbers of VNTRs in different places, they can be used to discriminate between two people.

DNA found at a crime scene is processed so that these sections can be compared to those from a sample swabbed from a suspect, or compared to a huge number of DNA profiles held on police databases. As well as helping to identify suspects, DNA profiling has helped prove the innocence of people incorrectly convicted, in some cases decades after the crime, and is often used to help identify victims, especially where people have been killed in large numbers or when their remains are badly damaged.

What's the smallest amount of DNA from which a suspect or victim can be identified?

As technology advances, scientists can process smaller and smaller samples to develop a DNA profile. Modern techniques can 'amplify' tiny

amounts of DNA from minute traces of any material that contains fragments of tissue or cells, such as blood, semen, saliva, urine, faeces, hair, teeth or bone. 'Low-level' or 'touch DNA' can sometimes even be collected from a few skin cells left behind after a person has touched an object or victim.

With a full sample and the latest DNA profiling techniques, investigators are able to generate a 'match probability' of up to one in a quintillion (1×10^{18}). The chance of a random person in the population having that DNA profile is infinitesimally small.

If a suspect's DNA is found at a crime scene, will it always lead to a conviction?

Not necessarily – there are all sorts of innocent reasons why a person's DNA could be at a crime scene or on a body. And even when DNA found at a crime scene is clearly that of the perpetrator, the police still need to find a match – if the murderer is not already a suspect, and their DNA profile is not on file, the evidence is effectively useless.

However, in such cases a person's own family can land them in it. A serial killer known as the Grim Sleeper, who killed at least 10 people in Los Angeles between 1985 and 2007, eluded police for decades, despite them having a sample of his DNA.

A suspect was finally apprehended when his son was arrested for weapons offences. The son gave a regulation DNA sample, which partially matched the DNA profile found at all of the Grim Sleeper crime scenes, which led the police to investigate his relatives. Police posed as waiters to get the father's DNA from a pizza slice, and found that it matched the crime scene DNA. He was arrested in 2010, but is yet to be convicted at the time of writing.

JARGON BUSTER

DNA phenotyping

Something of a holy grail for forensic scientists, DNA phenotyping would be the creation of a 'photofit' image based on a DNA sample alone. But our current knowledge of, and ability to analyse, DNA is not yet sufficiently advanced to make this a reality.



DNA profiling

A person's DNA profile is not simply their entire DNA sequence, which is billions of letters long. Instead, profiling compares the DNA in around a dozen highly variable stretches of the human genome.



Entomology

The study of insects. Forensic entomologists can work out the time of a victim's death by studying the types of insects feeding on their corpse.



Loops, whorls and arches

These are the classic patterns made by the ridges of skin in a fingerprint. Fingerprints are still commonly used to identify suspects today.



Match probability

This complicated calculation essentially gives the probability of a forensic match occurring by chance – for example, the likelihood that your DNA matches some DNA found at a crime scene which is not actually yours.



Palynology

The study of pollen and other tiny biological spores, which can link a suspect to a crime scene. Pollen is useful as it's very easy to pick up but very hard to remove from clothing, and is normally completely invisible to anyone other than an expert.

ANATOMY OF A MODERN CRIME SCENE

A man has been found murdered in a suburban home. The killer may have got away, but forensic scientists have plenty of evidence to pore over...

1 FINGERPRINTS

Prints can be recovered from surfaces. Their position helps detectives sequence events.

2 INSECTS

Insects on the body can help to determine when the victim died. Blowflies and then maggots arrive first, followed by beetles.

3 SALIVA

There may be visible bodily fluids, but DNA can be collected from less obvious sources such as a drinking glass.

4 VEGETATION

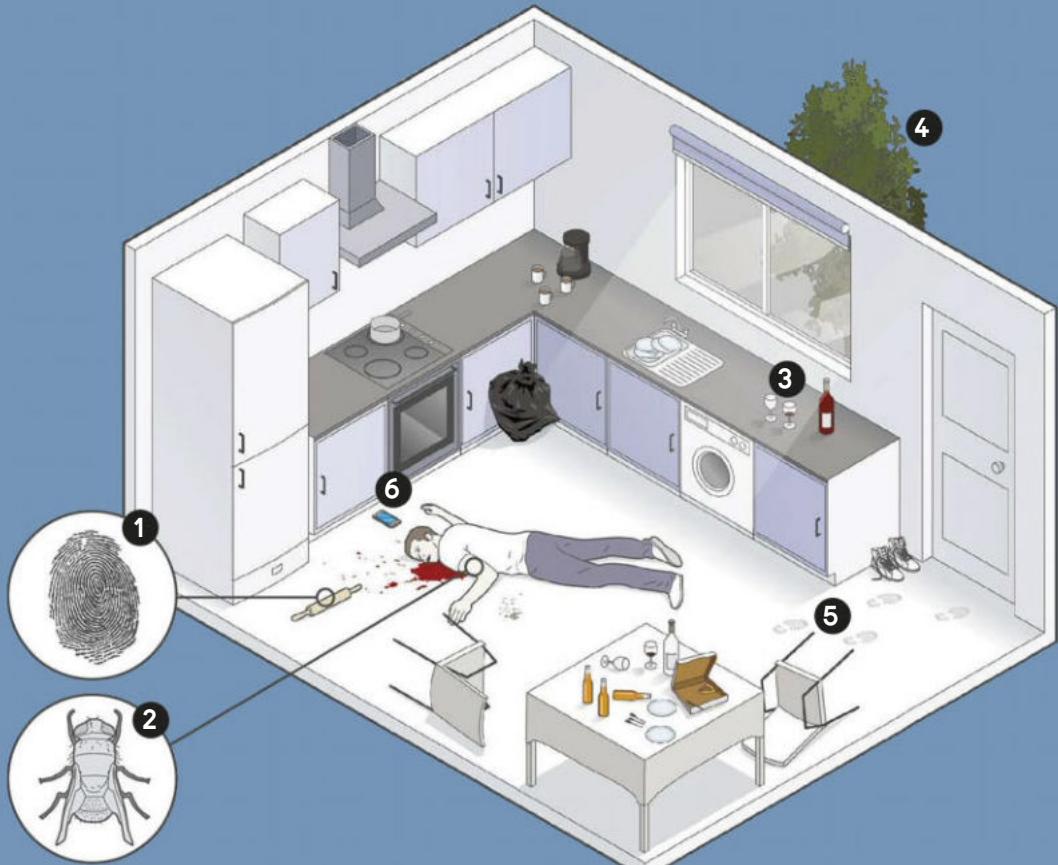
Pollen and spores from plants and fungi can stick to clothes or car tyres, linking suspects to a precise location.

5 FOOTMARKS

Forensics can recover a footprint that's almost invisible to the eye.

6 DIGITAL FOOTPRINT

With our smartphones, travel cards and online activity, most of us now leave a digital trace that can be easily followed.



WHAT WE STILL DON'T KNOW

1 WHO OWNS OUR DNA?

Police forces have been compiling large databases of DNA profiles for years, sometimes from people they've arrested but then released. Having the DNA profile of everyone in the country is a detective's dream, but others say it turns everyone into a suspect. With DNA-testing companies and the NHS also collecting DNA samples *en masse*, there's no easy answer to the question of who actually owns your genetic code, or what they can do with it.

2 HOW TO POLICE THE DIGITAL WORLD

Government security agencies are locked in a battle with technology giants over how to access evidence they say is crucial to preventing terrorism. Amazingly, even the FBI's digital experts can't unlock encrypted iPhones without the help of Apple. Even more worrying for security services is the burgeoning art of digital steganography – hiding secret messages within seemingly benign files such as holiday photos.



3 CAN DNA GIVE US AN IDEA OF WHAT A SUSPECT LOOKS LIKE?

Scientists have been able to map how certain genes are linked to certain facial features, but this relationship is immensely complex and not yet accurate enough to be useful. A DNA sample is also unlikely to ever be able to tell us whether someone is overweight or suntanned, as these are environmental, and not genetic, characteristics. Besides, you can always put on glasses or (if male) grow a beard.



In one tweet...

There's actually no such thing as 'forensic science'. Any science used in a criminal investigation is #forensicscience.

Can DNA evidence be faked?

Although DNA profiling is an excellent way to distinguish between individuals, it is still not immune to falsification, errors or manipulation. In 1992, a doctor and rapist called John Schneeberger evaded justice by injecting other people's blood into his arm just before his DNA was sampled by police. He was found guilty when forced to take another test years later.

It's also possible, although extremely rare, for a person to be a 'genetic chimera', meaning that they have cells in their body with different DNA from the rest of them.

Why do forensic scientists still use fingerprinting?

With fingerprints, police can often use their own in-house specialists rather than call on external forensic scientists. The digitization of fingerprint records means a photograph of a fingermark can be sent from a crime scene and compared to a database almost in real time.

According to the Fingerprint Society, fingerprints remain the number one ID metric for crime scenes in the UK, accounting for the identification of well over 100,000 suspects in 2012. Prints can also help indicate what someone was doing or how they entered a building – for example, if they are found leading up to a broken window or in a grip configuration on a weapon. And unlike DNA, it's hard to plant a fingerprint at a crime scene.

How accurate is it?

Fingerprints may be considered an 'older' forensic technique, having first been used in the 1890s, but the technology behind them is continuously being improved. As well as the well-known method of 'dusting' for fingerprints at the scene, forensics teams can also use



↑ Lonnie David Franklin Jr was arrested for the Grim Sleeper murders in 2010. At time of writing, his trial is still ongoing

chemical reagents and lasers to reveal extremely faint prints.

Even more sensitive tools can be deployed if objects are taken back to the lab. One method involves gold or silver particles being placed with a sample in a vacuum; the metal will settle on the faintest of marks.

Is everyone's fingerprint really unique?

The underlying patterns of ridges on people's digits are determined genetically, but the way individual ridges divide and break is dependent on conditions in the womb and the movement of the developing foetus. Even the fingerprints of identical twins will be different, while their DNA will be the same.

What else might police look for at a crime scene?

Criminals often wear gloves

while committing premeditated crimes, but they can't float in and out of the crime scene, so footprints can be crucial. While footwear can't definitively identify an individual, knowing the exact model of shoe the perpetrator wore is still very useful intelligence when looking for a suspect.

In more serious crimes, forensic ecologists will look for traces of biological material that can link a suspect to a certain area, such as the type of woodland where a body has been found. Pollen and fungal spores are especially important as they are picked up easily but not easily shed, even from clothing and footwear that's been washed. But suspects are likely to have walked through many types of soil, mud, or vegetation before and after being at a crime scene. It all adds up to a huge headache for

EXPLAIN IT TO A FRIEND

1 IT'S NOTHING LIKE TV

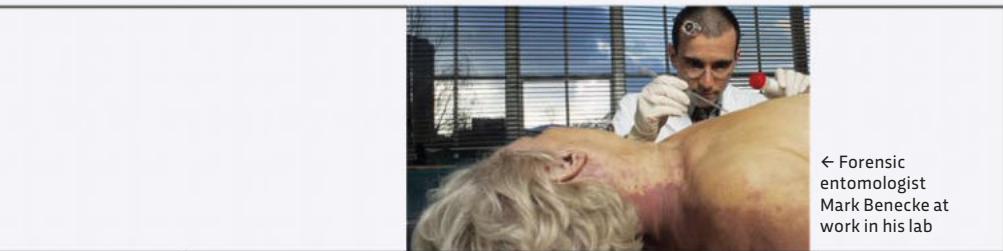
Forensic science, especially DNA analysis, can often involve tedious laboratory work – something that TV programmes usually neglect to show. For forensic evidence to hold up under scrutiny in court, every stage of the process – collection, handling, storage, and analysis – must be conducted to impeccable scientific standards.

2 PRINTS AND PROFILES

DNA and fingerprints are the most commonly used forensic evidence in criminal investigations. Apart from identical twins, no two people have the same DNA, and DNA samples are compared at points where the human genome is known to be incredibly varied. Fingerprints are still used, though, as they're cheaper to process and more likely to indicate what someone has been doing.

3 EXTRAORDINARY EVIDENCE

A huge range of materials can be collected and analysed to match a suspect to a crime scene. The more unique or rare the material, the more credible the case against them. It can be anything from pollen grains and mud to chemicals and even bacteria.



What is currently being developed at the cutting edge of forensic science?

those trying to analyse and compare all the biological material found on the suspect. The rarer the pollen or spore that forensics can match, the more credible the case.

A good example is also the first ever example of forensic ecology. In 1959, a man was murdered while travelling down the river Danube in Austria, but a body had not been found. Mud on the suspect's shoes contained a type of pollen from ancient hickory trees. Scientists concluded this could only have come from vegetation growing on exposed Miocene-age rocks, and the only place such soil had developed was a small section of the river 20km north of Vienna. Presented with this theory, the suspect confessed and took police to the body – exactly where the scientists had predicted.

Other techniques often seen on TV, such as blood spatter and ballistics analysis, may give detectives an idea of what happened at a crime scene, but rarely help find the perpetrator.

What can forensics teams learn from human remains?

In the first 72 hours after death, a pathologist is usually able to provide a reasonably accurate determination of the time and cause of death. If a person has been dead for longer, forensic entomologists may be called on to estimate the time of death, based on the number and type of insects feeding on the corpse. This method can be used to determine a period of hours, weeks or even years since death.

Blowflies are almost always the first insects to arrive and lay eggs on a corpse, as they are mobile, common and able to smell death from up to 10km away. Eventually other families of insects are attracted to the body, such as beetles. For more heavily decomposed or damaged

↓ Fingerprints have been used to identify criminals since the 1890s



remains, forensic dentists can match remnants of teeth to known dental records, or even use what they find to draw conclusions about the victim's age, size, gender, race and socioeconomic status.

What is currently being developed at the cutting edge of forensic science?

Forensic scientists can use anything to link a suspect to a crime scene, as long as they can prove the samples are unlikely to match by chance. In the US, scientists have looked at the atomic structure of fragments of glass to prove it was from the same sheet of glass as that found broken at a crime scene.

Pioneering techniques that mix digital forensics with anatomy are also now being used to identify people from small areas of their body seen in photos or videos. Features such as vein patterning or knuckle marks can identify suspects from images showing only small areas of their hands or arms. Grimly, this is likely to be used in cases involving sexual abuse.

As our understanding of DNA improves, we may one day be able to create a photofit-style image of a suspect solely from DNA evidence. However, such 'DNA phenotyping' is not yet accurate enough, and can't predict many aspects of how a person looks, such as whether they have a beard. ↗

Tom Ireland is a journalist and managing editor at the Royal Society of Biology.

DISCOVER MORE

Catching History's Criminals: The Forensics Story on the BBC Store: store.bbc.com/catching-historys-criminals-the-forensics-story

NEXT MONTH: HOW DO WE KNOW HOW THE HUMAN BRAIN WORKS?

OUT THERE

WHAT WE CAN'T WAIT TO DO THIS MONTH

APRIL 2016

EDITED BY JAMES LLOYD

DISCOVER MORE

For more TV, radio and events listings, check out #BrainFood, published every Friday on our website bit.ly/BBCFocusBrainFood



Steve Messam's bridge was made entirely from paper, yet was strong enough to walk across

PHOTO: STEVE MESSAM/PHAIION



01 DISCOVER MINI-ARCHITECTURE

NANOTECTURE:
TINY BUILT
THINGS BY
REBECCA ROKE

IS OUT NOW
 (£14.95, PHAIDON).

Ramblers in the Lake District's Grisedale Valley will have stumbled across an unusual sight last May. This bridge, the work of artist Steve Messam, was constructed solely out of 22,000 sheets of red paper (no bolts or adhesives were involved), wedged together to create a self-supporting structure. The paper bridge is one of 300 quirky and surprising structures featured in *Nanotecture*, a book dedicated to small-scale architecture. Other favourites include a transportable sauna, an inflatable house, a human-sized kaleidoscope and, we kid you not, a chalet for cats.



02

GET TO KNOW OUR INNER VOICES

People often describe their thoughts as being like a conversation between different voices of their consciousness. In his new book *The Voices Within*, psychologist CHARLES FERNYHOUGH explores this secret world. He talks to JAMES LLOYD

Your book is all about what you call 'inner speech'. What do you mean by this?

At its most simple level, it's the conversation that we have with ourselves. A lot of people experience it, but for many of us these inner voices are so intimate and familiar that we overlook them. Where do these words in our heads come from? What are they doing there? What functions do they serve?

Is this the same thing as our train of thought?

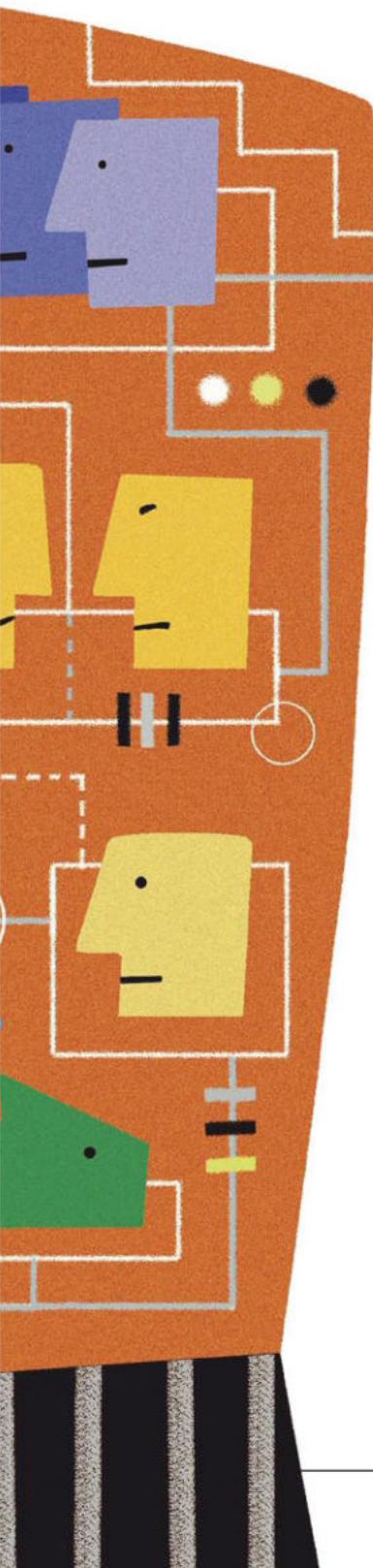
That's the big question. What do we mean by thought? The term 'thinking' gets used a lot, but it's a really woolly term and I think we should get rid of it. Can we carve off bits of what we'd call 'thinking' and say, "they have a voice-like quality"? In which case, let's call that inner speech.

How many people experience inner speech?

It's hard to put a number on that, because it's so difficult to find out. Most people would probably

"Inner speech has a self-regulatory function. We also use it to motivate ourselves, to gee ourselves up, to tell ourselves off, or just to express emotion"





say they talk to themselves in their heads, but there are also certainly some people who never use inner speech.

How do scientists study inner speech?

There's a technique called Descriptive Experience Sampling (DES) that was invented by the US psychologist Russell Hurlburt. This involves the participant wearing a beeper for a few hours, which beeps randomly. The participant's task is to note down what was going on in their mind just before the beep went off, and the next day they come into the lab to be interviewed about those moments. The most common thing people say to us is, "oh, this beep's really boring." But nobody's experience is boring – it's fascinating to find out what's in someone's mind.

We've just published the first studies integrating this technique with fMRI [functional magnetic resonance imaging]. When we captured inner speech happening naturally in the scanner, we found a lot of activation in a region of the brain linked with auditory perception. This suggests that spontaneous inner speech has a hearing/listening aspect to it.

Does inner speech serve a function?

Inner speech has a self-regulatory function – we talk to ourselves when we're planning or thinking through options. But we also use it to motivate ourselves, to gee ourselves up, to tell ourselves off, or just to express emotion. It does a lot of different things.

Is there a relationship between inner speech and the hallucinated voices that someone with schizophrenia, for example, might hear?

Hearing voices is typically associated with schizophrenia, but also with a number of other psychiatric conditions. Crucially, around 5 to 15 per cent of people without a psychiatric illness also report hearing voices. It's a much broader aspect of human experience than just a feature of mental illness. It can be distressing, but many people find it positive and uplifting too.

There might be a link between hallucinated voices and inner speech. There's a theory that when somebody hears a voice, they're generating inner speech, but for some reason they don't recognise it as their own work. It seems to come from somewhere else, so is perceived as an external voice.

THE VOICES WITHIN BY CHARLES FERNYHOUGH
IS PUBLISHED ON 21 APRIL (£16.99, PROFILE BOOKS).

03 **MEET COX AND INCE IN PUPPET FORM**

Brian Cox has lost his Wonder, and he's not happy. "Without my Wonder," he explains, "it's just equations with great hair." So he's enlisted the help of Robin Ince, and together they're setting out on a quest to find it.

That's the premise of a new mini-series starring Brian, Robin, and their puppet counterparts. Filmed at London's Science Museum, *The Quest For Wonder* is a heady mix of science, puppetry and comedy. Think *Avenue Q* meets BBC Radio 4's *The Infinite Monkey Cage*.

THE QUEST FOR WONDER

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04

BORE OURSELVES SMART

Everyone knows the mind-numbing feeling of being bored. But it's not all bad. Psychologist DR SANDI MANN reveals five reasons why boredom is good for us

1 IT INSPIRES CREATIVITY

When we're bored, we look for stimulation. When we can't get that physically by doing something exciting, we try to get it by daydreaming, allowing our thoughts to wander. This helps us to see things differently, to imagine and to innovate: all processes required for creativity. In a 2012 study, I found that 20 per cent of people believed that being bored made them more creative.

2 IT MAKES US KINDER

Our boredom, it seems, may benefit others too. A 2011 study at the University of Limerick found that being bored can inspire people to be altruistic, empathetic and to perform good deeds such as giving to charity, volunteering or even donating blood. According to the researchers, when we're bored, we lack meaningfulness and so are more likely to seek out kind and meaningful activities.

DON'T MISS**ALL IN THE MIND**

Claudia Hammond delves into the human psyche in a new series of *All In The Mind*, starting 26 April on BBC Radio 4.

5 IT HELPS US SOLVE PROBLEMS

Daydreaming can also help us to solve problems. Daydreaming is a subconscious process that allows us to try out different ideas and solutions as many times and in as many ways as we wish. The benefit of this is that our minds can explore seemingly illogical ideas in new ways – very handy if you're stuck on that final crossword clue.

**3 IT INCREASES OUR ATTENTION SPAN**

Constant stimulation may appear to keep us from being bored, but novelty is addictive. We get a dopamine hit each time we experience something new, but as we become accustomed to this we seek ever newer and more exciting stimulants to satisfy our dopamine cravings. This means that we lose the ability to focus on one unchanging stimulus for a long time. However, allowing ourselves to be bored can start to undo that.

4 IT GIVES US TIME OUT

We live in a world of 24/7 connectivity. Our minds are constantly active, alert and primed – for emails, status updates, messages and news flashes. Allowing boredom into our lives gives us time out from this ceaseless buzz. It helps us to enter a state of mindfulness, to appreciate where we are and who we are, and to momentarily slow down the rollercoaster of life.

THE UPSIDE OF DOWNTIME: WHY BOREDOM IS GOOD BY SANDI MANN

IS OUT NOW (£13.99, ROBINSON).

KATY HUFF SHARES HER FAVOURITE HAUNTS IN SAN FRANCISCO



San Francisco has gorgeous weather and beautiful architecture. And I also appreciate the escalator etiquette: San Franciscans stand to the right and walk to the left. Efficient!

The city is like New York for its high density of people and ideas, as well as the bleeding-edge pace of things. Even if you aren't involved in the start-up universe, it touches everything in the Bay. Everyone here seems to be in the most idealistic phase of their lives.

One place which is definitely open to everyone is the **EXPLORATORIUM** ①. This is a cool science museum, kinetic playground and fully fledged laboratory – it's huge. The **CALIFORNIA ACADEMY OF SCIENCES** ② is also great to visit, and has an incredible multistorey, rainforest-like biome. It also hosts regular adults-only evenings called 'NightLife' where you can wander around (without kids underfoot) and listen to live music with a drink in your hand. I also love going to Nerd Nite, which is held at various places around the city. It combines a

beverage with presentations on science, history, society, literature or art.

I often meet friends at **DOLORES PARK** ③, which has a great views over the city and the Bay. And I love the sight of the **GOLDEN GATE BRIDGE** ④ from Baker Beach.

For food, I head to the **TANDOORLŌIN** ⑤. This is the nickname for a block of Indian and Pakistani restaurants in the Tenderloin neighbourhood. My husband and I are vegetarians – we tend to eat there once a week as they have a great selection of veggie dishes. My favourite is the palak paneer.

For drinks, I love hanging out at **BOURBON & BRANCH** ⑥ a former 'speakeasy'. In the US, during the 1920s and 30s, alcohol was banned under Prohibition, so many bars operated secretly behind closed doors, requiring passwords for access. Today, this cool bar has passwords on the door and secret rooms behind bookshelves. Ask the bartender for their favourite whiskey. After that get a Revolver. After that, a classic Manhattan. After that... **F**

① EXPLORATORIUM

A hands-on science museum, with workshops plus indoor and outdoor exhibits.
Pier 15, Embarcadero
exploratorium.edu

② CALIFORNIA ACADEMY OF SCIENCES

Billed as a natural history museum "dedicated to exploring, explaining and sustaining life on Earth".
55 Music Concourse Drive
calacademy.org

③ DOLORES PARK

Stunning city park, located two blocks south of Mission Dolores at the western edge of the Mission district.
19th and Dolores St

④ GOLDEN GATE BRIDGE

The iconic suspension bridge is named after the Golden Gate strait that connects San Francisco Bay to the sea.
goldengatebridge.org

⑤ TANDOORLŌIN

A block of Indian and Pakistani restaurants in the Tenderloin neighbourhood.

⑥ BOURBON & BRANCH

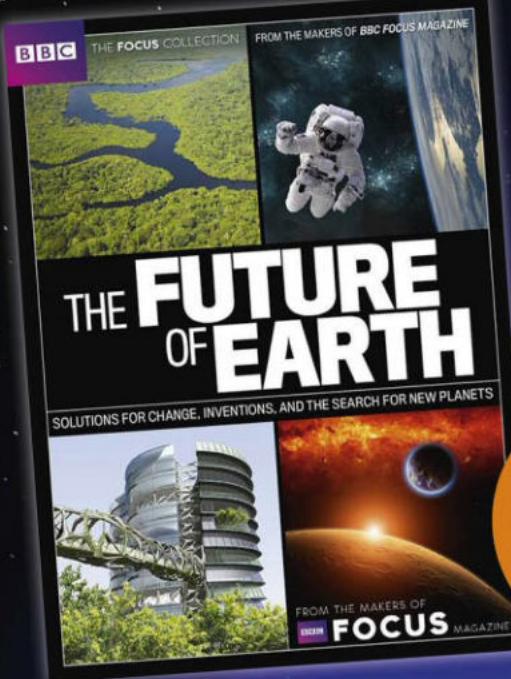
A former speakeasy, which is now a trendy bar.
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bourbonandbranch.com

Katy Huff is a postdoctoral scholar at the University of California, Berkeley. Her work focuses on nuclear power.



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EVERYDAY SCIENCE

Busting the myths of modern life

Is there any such thing as a superfood? Do we really need eight hours sleep? Are right-brained people more creative? We separate fact from fiction.

HEALTH

THE REAL INNERSPACE

A submarine that journeys through the body curing our ills might not be too far away. We look at disease-fighting nanomachines and nanobots.



SPACE

OUR FUTURE ON MERCURY

Often the forgotten planet in our Solar System, could mineral-rich Mercury be the perfect launch pad to the rest of the Milky Way?



NATURE

DAVID ATTENBOROUGH

Ahead of his 90th birthday, we speak to the celebrated BBC presenter and naturalist about his extensive career.

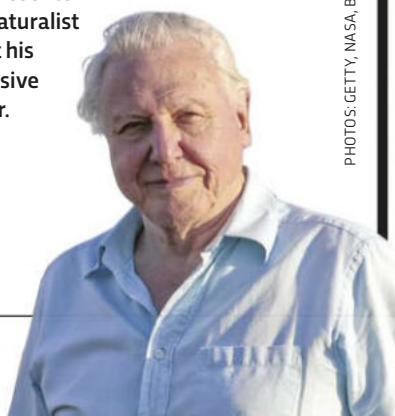


PHOTO: GETTY, NASA, BBC

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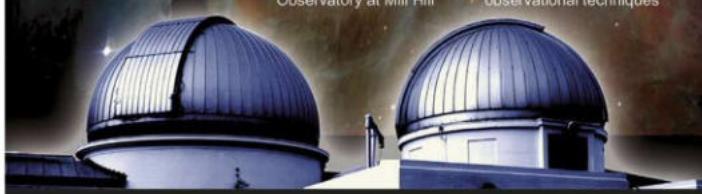
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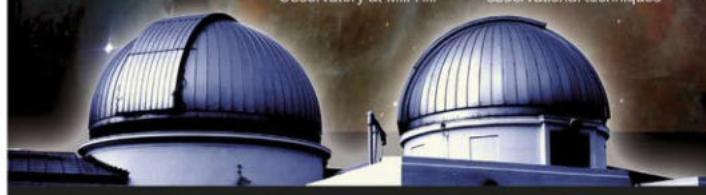
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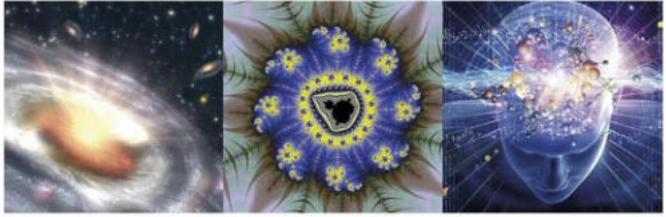
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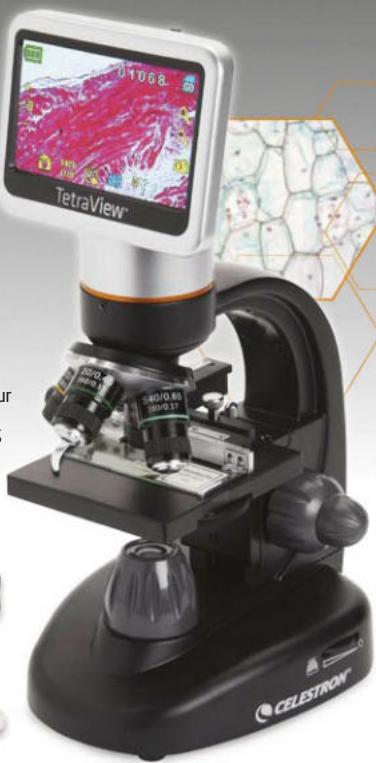
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"A report commissioned by Prince Charles claimed no end of dangerous nonsense"

Edzard Ernst is emeritus professor of complementary medicine at Exeter University. He explains to Helen Pilcher how he's standing up for science

Both my father and grandfather were doctors, so in a way I was destined to become a medic too. But before I studied medicine, I studied psychology and became a musician. I played the clarinet, saxophone and drums. For a long time, I considered myself a professional jazzer and an amateur medic!

My first medical job was at a homeopathic hospital in Munich. When you are studying medicine you don't have time to think critically because there is so much to take in, so I was actually quite impressed with what I saw.

When I took a job as a researcher, it changed my life. It turned me into a scientist and a critical thinker.

I never look for controversy, but there have been a few times when I've found myself in the thick of it. The first was when I was professor at the Medical Faculty of Vienna. I did some research into the Nazi occupation of Austria and disclosed how the Nazi 'cleansing' of the medical faculty led to unspeakable atrocities. Austria wasn't ready for this, and I felt like the evil spirit hadn't quite vanished from my own faculty.

In 1993 I moved to England to take up my position at Exeter University. I expected a peaceful backwater and had no idea how contentious the new job would turn out to be.

I tried to rigorously test alternative medicine and keep a low profile, but after about 15 years of research I became more outspoken. At this stage, it was blatantly obvious that well over 90 per cent of the claims made by enthusiasts were not just wrong but often dangerous too. Disclosing this undeniable fact was nothing less than my duty, but it did not exactly increase my popularity.

In 2005, I couldn't help but criticise a report that Prince Charles had commissioned which claimed no end of dangerous nonsense. Charles' secretary filed an official complaint. The worst for me was the abominable lack of support from my own university. I was treated as 'guilty until proven innocent'. Although in the end I was cleared of any wrongdoing, it led to the closure of my research unit.



I'm quite a shy person. I think more than I talk.

Sometimes I can be stubborn, but I try to be honest and sometimes brave. Last year, I was awarded the John Maddox Prize for Standing Up For Science. I'm really chuffed with that. So much of my life has been about defending science, transparency and integrity.

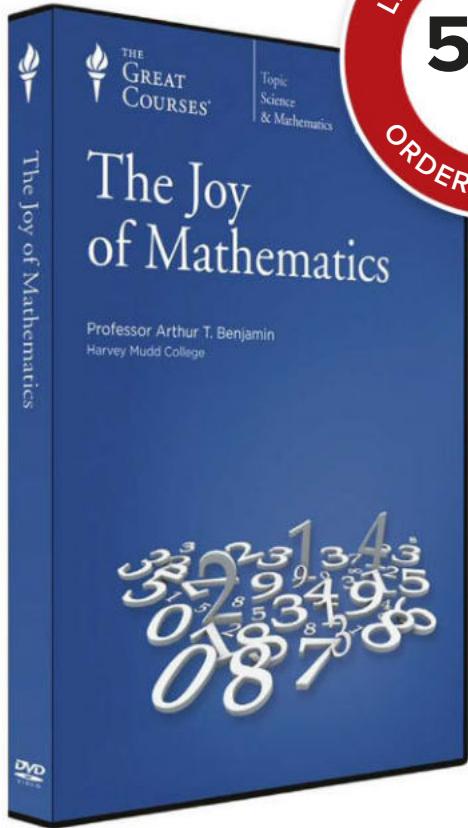
Edzard Ernst is a qualified doctor and rigorously researches alternative medicine. He is also editor-in-chief of two journals.

DISCOVER MORE

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NEXT ISSUE: JOCELYN BELL BURNELL

I write something almost every day. It helps me to relax. I have my blog and I continue to publish books. I also have two drum kits at home. Sometimes I join my old band, The Jazz Kids, and we play together. Considering our age, we should perhaps rename ourselves as The Swinging Zimmerframes! ☺



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